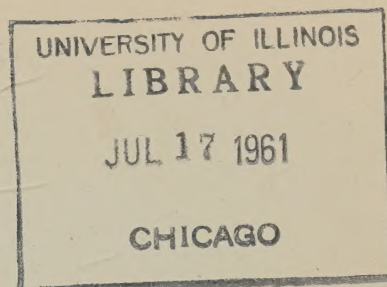


1961  
62  
**ence Abstracts**

**Section A**



# **Physics Abstracts**

**Published by  
the Institution of  
Electrical Engineers**

**Vol. 64 No. 762**

**June 1961**

**6689—7965**

# Physics Abstracts

Volume 64

JUNE 1961

Number 762

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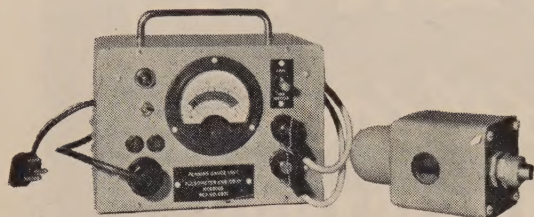
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VOL. 106 (1959) PART B Supplement 14 (Convention on Stereophonic Sound Recording, Reproduction and Broadcasting)

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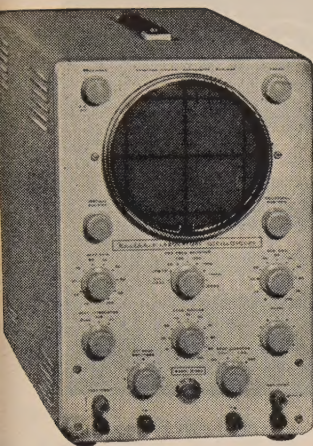
VOL. 107 (1960) PART B Supplement 19 (Symposium on Data Handling and Display System for Air Traffic Control)

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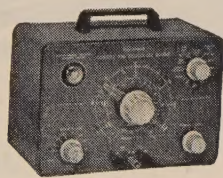
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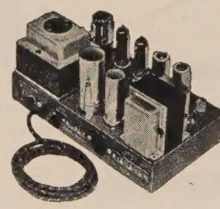
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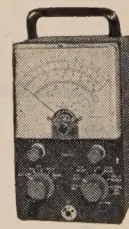
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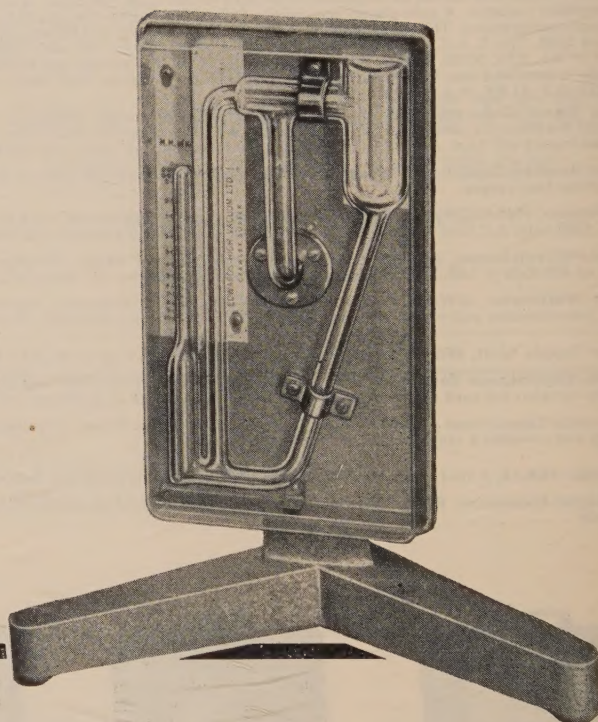
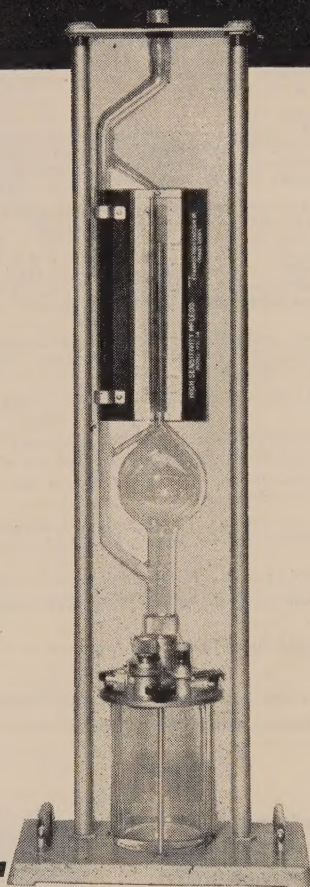
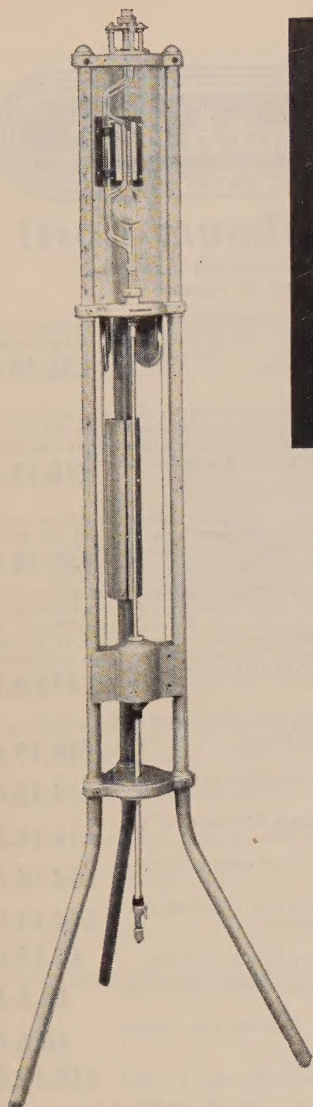
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# PHYSICS ABSTRACTS

Volume 64

JUNE 1961

Number 762

## MATHEMATICS

6689 **SIMPLIFYING THE FOURIER INTEGRAL BY ADEQUATE SPECIFICATION.** C.G.Mayo and J.W.Head.  
Brit. J. appl. Phys., Vol. 12, No. 5, 248-50 (May, 1961).  
Most of the difficulties associated with the Fourier integral vanish if the conceptual unit impulse (Dirac delta function with Dirac's unit closed), which plays an important part in the derivation of the integral, is replaced by a form in which the limiting technique is maintained. This form may be regarded as the output voltage resulting when a conceptual unit impulse of current flows in a unit "resistance" shunted by residual capacitance. It can be represented as a function of time by the expression  $\eta^{-1}e^{-t} \int_0^t \mu H(t) dt$ , where  $\eta$  representing the residual capacitance, is vanishingly small but not zero. It is the presence of this quantity  $\eta$  which removes all ambiguities and difficulties. In the usual treatment of this question in terms of Jordan's lemma, a residual term is neglected which is estimated in terms of the size of a relevant integrand; if, however, the oscillatory nature of this integrand is also taken into account, the residual is found, as here shown, to be an absolute zero.

**WIGNER COEFFICIENTS FOR THE  $R_4$  GROUP AND SOME APPLICATIONS.** See Abstr. 6784

**A SIMPLE APPROXIMATION TO THE EXCHANGE INTEGRAL OF QUANTUM CHEMISTRY.** See Abstr. 6027

6690 **THE PHYSICS OF COMPUTER ELEMENTS.** C.N.W.Litting.  
Brit. J. appl. Phys., Vol. 12, No. 5, 207-13 (May, 1961).

The main requirements of a computing machine are that it should be able to receive and store information, perform logical operations on the information and finally to produce some form of useful output. Some interesting techniques employed in satisfying these requirements are described together with the physical phenomena on which they depend. The main use of novel techniques is in the storage of information and various systems are examined which depend on different physical principles. The following types of system are considered: acoustic, electrostatic, magnetic, optical and superconducting. It is considered that, at present, magnetic or superconducting devices employing thin films show most promise for the development of high speed devices.

## ASTROPHYSICS

6691 **AN INTRODUCTION TO CELESTIAL MECHANICS.** T.E.Sterne.  
New York, London: Interscience Publishers (1960) xi + 206 pp.  
This has been written with the current, and presumably increasing future, interest in view. It is aimed at readers well grounded in the physical sciences and mathematics but who have little familiarity with astronomy. There are six chapters headed as follows: (1) Gravitation, The One- and Two-body Problems, Geodesic Motion. (2) The Attraction of Irregular Bodies, Rotational Distortion. (3) Coordinates, the Orbit in Space, Time, Ephemerides, Emission. (4) Dynamics, Variation of Elements, Perturbations. (5) General Perturbations of Artificial Earth Satellites, The Inference of Atmospheric Density. (6) Numerical Integration of Ordinary Differential Equations, Special Perturbations.

6692 **SECULAR TERMS AND FLUCTUATIONS IN THE MOTIONS OF THE SUN AND THE MOON.** J.van der Waerden.  
Astron. J. (USA), Vol. 66, No. 3, 138-47 (April, 1961).  
The deviations  $\Delta L$  and  $\Delta L'$  between the observed and tabular longitudes of the moon and the sun are due to two causes. The first is the friction of the tides, resulting in a secular retardation of the rotation of the earth, and the reaction of this friction resulting in a secular retardation of the true motion of the moon. The second is the irregular rotation of the surface of the earth due to ocean currents in the interior of the earth. A probabilistic theory of these fluctuations is developed. By a modified method of least squares, the coefficients of the secular terms are determined from modern and ancient observations.

6693 **COOLING OF THE INTERSTELLAR CLOUDS IN THE REGION OF NEUTRAL HYDROGEN.** S.Takayanagi and S.Nishimura.  
Publ. Astron. Soc. Japan, Vol. 12, No. 1, 77-105 (1960).  
Previous theoretical calculation of the collisional excitation

rate of rotation of  $H_2$  is extended to a wider range of temperature and also to transitions between higher excited rotational states of rotation. Relative importance of other cooling processes is also estimated. Assuming that the cloud-cloud collision process proposed by Kahn is the most efficient heating process, the cooling equation is solved. The electron-ion collisions, the collisional excitations of rotation of  $H_2$  and other molecules, and the collisions between H atoms and grains are taken into account. Numerical examples are given for the cooling curve and the mean cloud temperature, which is compared with 125°K obtained from 21 cm observation. The ambiguity in the assumed number densities of positive ions,  $H_2$  and other molecules are discussed. A doubt is raised as to the efficiency of the Kahn process of heating. Low-energy cosmic-ray particles are considered to be one of the other possible energy sources.

6694 **HEATING OF INTERSTELLAR CLOUDS BY SUPRATHERMAL PARTICLES.** S.Hayakawa  
Publ. Astron. Soc. Japan, Vol. 12, No. 1, 110-12 (1960).

On the basis of a recent work by Takayanagi and Nishimura (see preceding abstract), the temperature of H I clouds is interpreted in terms of the equilibrium between cooling discussed by the above authors and heating due to ionization by suprathermal particles. The suprathermal particle intensity is thus found to be of the order of  $1 \text{ cm}^{-2} \text{ sec}^{-1}$ , in reasonable agreement with the value anticipated from cosmic-ray evidence.

6695 **A POSSIBLE ORIGIN OF THE ULTRAVIOLET RADIATION FROM GALACTIC CLOUDS.** S.Hayakawa.  
Publ. Astron. Soc. Japan, Vol. 12, No. 1, 113-14 (1960).

It is suggested that the unexpectedly strong ultraviolet radiation from various parts of the Galaxy may be due to the de-excitation of atoms excited by suprathermal particles which are found to be responsible for the temperature H I clouds, as shown in the preceding

ing paper (see preceding abstract). The suprathermal particles intensity of about  $10^2 \text{ cm}^{-2} \text{ sec}^{-1}$  can account for the strong ultraviolet radiation.

6696 ON THE ORIGIN OF DEUTERIUM IN THE SOLAR SYSTEM. S.Hayakawa.

Publ. Astron. Soc. Japan, Vol. 12, No. 1, 115-16 (1960).

The observed abundance of deuterium is assumed to be peculiar to our solar system. At a stage of formation of the solar system there occurred a strong outburst of suprathermal particles which irradiated heavy nuclei to produce deuterons. Volatile elements, including most of hydrogen, had been dissipated before that stage, so that the ratio of deuterium to hydrogen could be as high as the observed one.

INTERPLANETARY MAGNETIC FIELD AND THE AURORAL ZONES. See Abstr. 6635

APPROXIMATE EMPIRICAL RELATION BETWEEN THE SECULAR MAGNETIC VARIATION AND THE FLUCTUATIONS OF THE EARTH'S ROTATION. See Abstr. 6650

6697 THE THERMAL RADIATION OF THE MOON AT 1420 Mc/s. P.G.Mezger and H.Strassl.

Planet. Space Sci. (GB), Vol. 1, No. 3, 213-26 (Aug., 1959).

Measurements of the thermal radiation of the moon at 1420 Mc/s have been made with the continuum receiver of the 25 m radio telescope of Bonn university. The measurements cover about three lunations (30 April to 22 July 1958). The observations and their reduction are described in detail. It is found that — within the working accuracy of about  $\pm 2\%$  relatively — the radiation temperature of the moon at 1420 Mc/s shows no variation with the phase of the moon. This may be explained by the fact that the observed radiation has its origin at some depth underneath the moon's surface where the periodic variations of heating from the sun have become insignificant. The mean value of the radiation temperature at 1420 Mc/s is found to be  $250.2^\circ$  with an estimated absolute uncertainty of about  $\pm 12\%$ .

6698 INTERIOR OF THE MOON. G.J.F.MacDonald.

Science (USA), Vol. 133, 1045-50 (April 7, 1961).

Nonspecialist article which discusses possible theories.

6699 THE AIRGLOW OF VENUS. G.Newkirk, Jr.

Planet.Space Sci. (GB), Vol. 1, No. 1, 32-6 (Jan., 1959).

Low dispersion, high speed spectra of the unilluminated portion of Venus show emission features at 4415 Å and 4435 Å which agree in position with those found by Kozyrev [Izvestiya Krÿmskoi Astrofizicheskoi Observatorii (USSR), Vol. 12, 169 1954]. Kozyrev's other emission bands are not corroborated by these spectra. A previously unreported emission band may be present at 4505 Å. The radiance of the emission bands centred at 4420 Å is about eighty times that of the 5577 Å line of the terrestrial airglow. It is unknown whether the emission from the dark side of Venus is of airglow or auroral character.

6700 MULTICOLOR PHOTOMETRY OF MARS IN 1958. G.de Vaucouleurs.

Planet. Space Sci. (GB), Vol. 2, No. 1, 26-32 (Oct., 1959).

Photoelectric observations of Mars in October and November 1958 at the Lowell Observatory give values of the stellar magnitude and integral albedo at five wavelengths from  $\lambda$  3300 to  $\lambda$  6900. In the near ultraviolet  $3000 < \lambda < 4000$  Mars is "grey" and very dark, with a nearly constant albedo  $A = 0.046$ . Earlier Mount Stromlo and Flagstaff data are also discussed.

6701 DISSIPATION OF PLANETARY ATMOSPHERES. V.A.Firsoff.

Science (USA), Vol. 130, 1337 (Nov. 13, 1959).

6702 DENSITY OF THE LUNAR ATMOSPHERE. J.C.Brandt.

Science (USA), Vol. 131, 1606 (May, 27, 1960).

The minimum possible density of the lunar atmosphere at the surface is shown to be essentially the value for the interplanetary medium. This value, when combined with the observed maximum, places the particle density between  $10^3$  and  $10^6 \text{ cm}^{-3}$ , while the electron density must be about  $10^3$  to  $10^4 \text{ cm}^{-3}$ . These results are markedly different from those recently obtained by Firsoff (preceding abstract).

6703 DENSITY OF THE LUNAR ATMOSPHERE. V.A.Firsoff; J.C.Brandt.

Science (USA), Vol. 131, 1669-71, 1671 (June 3, 1960).

Firsoff comments on a paper by Brandt (preceding abstract) and replies to criticisms therein of an earlier paper. In a follow-up note Brandt rejects Firsoff's remarks and makes further comments on his work.

6704 THE DENSITY DISTRIBUTION OF CHARGED PARTICLES IN METEOR TRAILS.

T.L.Perel'man and S.I.Anisimov.

Dokl. Akad. Nauk SSSR, Vol. 136, No. 4, 810-12 (Feb. 1, 1961). Russian.

Expressions are obtained for the density, as a function of time and radial distance in the trail, in terms of a dimensionless parameter  $\epsilon$ , the ratio of the rates of change of density due to recombination and diffusion. [English translation in: Soviet Physics — Doklady (USA)]. G.A.Chis

6705 THE FALL-OUT OF METEORIC IRON PARTICLES. E.A.Kreiken.

Planet. Space Sci. (GB), Vol. 2, No. 1, 39-48 (Oct., 1959).

A survey of the attempts made during recent years at the Astronomical Institute of the Ankara University: (1) to determine the daily amounts of the fall-out of iron particles of meteoric origin; (2) to study the seasonal variations of the fall-out; and (3) to compare the curve representing these seasonal variations of the fall-out with the one representing the seasonal variations in meteoric activity. The results so far obtained are critically discussed and possibilities for improving the methods of observations are indicated.

6706 METEORITIC DUST MEASURED FROM EXPLORER M.Dubin.

Planet. Space Sci. (GB), Vol. 2, No. 2-3, 121-9 (April, 1960).

The impacts of micrometeorites upon the cylindrical shell of the satellite 1958  $\alpha$  were monitored by a calibrated piezo-electric detector. Results of these measurements are presented, including a description of the instrumentation, the calibration procedure, the amount and type of data recorded at the ground stations. The total data sample over a period of 12 days of telemetering consists of 78 890 sec of telemetered data with an excellent signal-to-noise ratio. During this time 153 signals denoting impacts by micrometeorites were recorded. This is equivalent to  $1.7 \times 10^{-2}$  impacts  $\text{m}^{-2} \text{ sec}^{-1}$  on the earth. The calibration indicates that for a mean impact velocity of 30 km/sec the particles striking the satellite had a mass of  $8 \times 10^{-10} \text{ g}$  or larger, if no large deviation in momentum transfer occur during the formation of hypervelocity craters. Thus, the accretion rate of extraterrestrial dust upon the earth may be estimated at 10 000 tons/day during the month of February 1958. A variation from day to day of the influx rate as large as an order of magnitude is evident from the data. A "show" of dust particles has been found for the third day in orbit. A variation of the influx of particles may also be attributed to a diurnal effect from the earth's rotation and its heliocentric velocity.

6707 SOLAR SPECTROSCOPY IN THE FAR ULTRAVIOLET. R.Tousey.

J. Opt. Soc. Amer., Vol. 51, No. 4, 384-95 (April, 1961).

The programme conducted from rockets by the Naval Research Laboratory, is described from its inception, in 1946, to the present. Included is a brief historical account of the gradual discovery in the laboratory of the ultraviolet and extreme ultraviolet.

OSCILLATOR STRENGTHS OF LEAD AND THE LEAD ABUNDANCE IN THE SUN. See Abstr. 5970

NON-UNIFORMITY OF SOLAR CORPUSCULAR STREAMS. See Abstr. 6646

6708 PHOTOELECTRIC STUDY OF SUNSPOTS. M.Makita and M.Morimoto.

Publ. Astron. Soc. Japan, Vol. 12, No. 1, 63-76 (1960).

The continuum of sunspot spectra was observed simultaneously at three wavelengths with a telescope, using a photoelectric device and a rotating prism which reduced the effect of scintillation appreciably. The relation of the intensity ratio to the area and limb effect of sunspots were obtained and from the latter the temperature distribution is derived for the penumbra and the umbra ( $5500^\circ \text{ K}$  and  $4100^\circ \text{ K}$  at  $\tau \sim 0.5$  respectively). The obtained temperature distribution of the umbra with the area =  $70 \times 10^{-6}$  of solar hemisphere is on the average  $500^\circ \text{ K}$  lower than Michard's (Abstr. 996 of 1954).

- 6709 ON THE STRUCTURE OF THE SUNSPOT ZONE. B.Bell.  
*Smithsonian Contrib. Astrophys. (USA)*, Vol. 5, No. 3, 17-28 (1960).  
 Published data on the magnetic field strengths and numbers of sunspots for the years 1917-1958 are used to study the structure of the sunspot zone as a function of heliographic latitude. Some evidence is presented in favour of the hypothesis that several zones of activity develop in each solar hemisphere, and that these zones remain stationary in latitude and are just sufficiently out of phase to simulate the latitude shift over the solar cycle described by Beer's law. A caterpillar diagram is proposed to supplement the all known butterfly diagram.
- 6710 ON THE HYDROMAGNETIC WAVE-FRONTS IN THE SOLAR ATMOSPHERE. WAVE-FRONTS OF SMALL AMPLITUDE IN THE NONUNIFORM MEDIUM WITH WEAK MAGNETIC FIELD. A.G.Pacholczyk.  
*Atti Accad. Sci. Torino I (Italy)*, Vol. 94, No. 6a, 823-31 (1959-60).  
 A general expression is obtained for the shape of axisymmetric wave fronts in a compressible atmosphere subject to a uniform gravitational field and a weak magnetic field. The cases of uniform and of isothermal atmospheres are considered. R.A.Newing
- 6711 THE ABSOLUTE MEASUREMENT OF MONOCHROMATIC ENERGY BETWEEN 6000 Å AND 8600 Å ADMITTED FROM THE CENTRE OF THE SOLAR DISK. Peyturaux.  
*R. Acad. Sci. (France)*, Vol. 252, No. 5, 668-9 (Jan. 30, 1961). French.  
 The solar energy is compared directly with that from a black-body source consisting of a tantalum cylinder heated in vacuo to 3000°K. Energy from both sources is passed through a monochromator, and measured with a PbS cell. Corrections to the measurements to allow for atmospheric extinction are obtained with ancillary apparatus simultaneously with the solar observations. All measurements were made at 1600 m above sea level. Provisional results indicate that the previously accepted value of the absolute solar energy in the infrared spectral region needs to be increased by ~5%. D.R.Barber
- 6712 A STUDY OF Si X EMISSION FROM THE OUTER LAYERS OF THE SUN. C.Pecker.  
*R. Acad. Sci. (France)*, Vol. 252, No. 8, 1107-9 (Feb. 20, 1961). French.  
 Gives a discussion of the theoretical conditions relevant to the emission of radiation from strongly-ionized Si atoms in the solar atmosphere. Since Si is one of the most abundant of solar atoms, it appears worthwhile to search for lines attributable to transitions from the higher ionization levels in both ultraviolet continuum and emission spectra. The more probable of these transitions are listed; the masking effects of blended lines of other elements are noted. D.R.Barber
- 6713 A REMARKABLE ERUPTION NEAR THE SUN'S LIMB ON 1 JUNE, 1960. D.Belorizky.  
*R. Acad. Sci. (France)*, Vol. 252, No. 4, 512-13 (Jan. 23, 1961). In French.  
 A detailed discussion of five solar spectrograms taken throughout between 08h 45m and 10h 45m UT at a dispersion of 8 Å/mm. The spectral range covered was 3820 to 4120 Å. A solar event was observed visually in H $\alpha$  light 10 min previously. In addition to the very strong emission lines of H, and Ca II(H, K), many lines of Fe I, Mg I, Ca I, Si I, Ti I, Al I, Mn I, Si II, Ti II, and Sr II were present in emission. Displacements due to flare-charge motions were measured in the first spectrogram at both H and K lines, yielding a mean Doppler velocity of 280 km/sec. This solar event was followed by an intense ionospheric disturbance from 0h 40m to 09h 45m UT. A geomagnetic storm commenced at 0h 30m UT on June 4. The interval between flare, and storm onsets implies a solar particle velocity of ~640 km/sec. D.R.Barber
- ASSOCIATION OF SOLAR RADIO BURSTS WITH AURORAL STREAMS. See Abstr. 6641
- SOLAR CORPUSCULAR STREAMS AND FAMILIES OF GEOMAGNETIC STORMS. See Abstr. 6652
- FLARE-ASSOCIATED BURSTS AT 18 Mc/s. See Abstr. 6728

- FLARE PUFFS AS A CAUSE OF TYPE III RADIO BURSTS. See Abstr. 6731
- BURSTS OF MICROWAVE RADIO EMISSION ASSOCIATED WITH SOLAR FLARES. See Abstr. 6733
- UNUSUAL DECREASE OF MICROWAVE SOLAR RADIO EMISSION DURING THE FLARE ON NOVEMBER 30, 1959. See Abstr. 6742
- 6714 RESULTS OF THE 1954 ZÜRICH SOLAR ECLIPSE EXPEDITION. VII. PHOTOMETRY AND POLAR RAYS. M.Waldmeier.  
*Z. Astrophys. (Germany)*, Vol. 51, No. 4, 286-96 (1961). In German.  
 For previous work see Abstr. 11741 of 1959. Using a photograph taken with a camera of 8 m focal length, the polar rays of the corona of June 30, 1954, were analysed photometrically in the region of  $\pm 20^\circ$  polar distance and for the interval  $r = 1.15$  to  $1.60$ . As the mean intensity is about 21% higher on the rays than for the zones between them, the electron density would be 5 times higher for the ray than for its surroundings, supposed that the ray is considered as a single isolated one in a region without other structure. More probably the intensity between the rays is due to rays that are not resolved. Thus, much higher values would result for the ratio of the densities on the ray and in its surroundings. Most likely the brightest and largest rays arise from several rays lying in the same line of sight. In general, the observed pattern of the polar plumes does not show the individual rays but rather a statistical superposition of them.
- 6715 A LIST OF NEW OB STARS NEAR THE GALACTIC NEBULA M17. C.B.Stephenson and R.W.Hobbs.  
*Astron. J. (USA)*, Vol. 66, No. 4, 186-7 (May, 1961).  
 Since radio observations may indicate a Stromgren-spherelike electron distribution near the radio centre of M17, the area was screened for fainter OB stars than those hitherto known, since none of the latter lie very near the radio centre. Precautions were taken to suppress the nebula light on the plates. Lists and an identification chart for faint OB stars in the area are given. Two of the new stars lie within ~4' of the radio centre, but the field is too rich in faint OB stars to conclude from the surface distribution that these two are probably physically associated with the ionization.
- 6716 FORTY-FIVE VARIABLE STARS IN VSF 193. D.Hoffleit.  
*Astron. J. (USA)*, Vol. 66, No. 4, 188-91 (May, 1961).  
 Results of photographic observations of 17 known and 28 new variable stars in VSF 193 in Sagittarius are given. Thirty-one are Mirs-type stars, including V 939 Sgr which had previously been considered an RT Serpentis star.
- 6717 ON THE ESTIMATE OF THE ASYMPTOTIC VALUE OF OPTICAL THICKNESS OF A SPHERICALLY SYMMETRIC STELLAR ATMOSPHERE IN THE NON-CONSERVATION CASE IN THE SECOND APPROXIMATION. K.K.Sen.  
*Indian J. theor. Phys.*, Vol. 7, No. 3-4, 45-52 (Sept.-Dec., 1959).  
 The value has been calculated for the non-conservative isotropic scattering case. The Wick-Chandrasekhar method is used for solving the integro-differential equation of transfer appropriate to the problem.
- 6718 STELLAR MODELS WITH PARTIALLY DEGENERATE ISOTHERMAL CORES. K.Suda and Z.Hitotuyanagi.  
*Publ. Astron. Soc. Japan*, Vol. 12, No. 1, 21-7 (1960).  
 Stellar models consisting of partially degenerate isothermal cores and radiative envelopes are considered for a given chemical composition. It is found that the character of evolutionary sequences as the degeneracy develops in the core depends on the stellar mass. For masses less than about  $1.5M_\odot$ , there appears no upper limit to the core mass, in contrast to the non-degenerate case. For larger masses, the results are nearly the same as those of the Schönberg-Chandrasekhar sequence.
- 6719 INVESTIGATIONS OF ROTATING STARS. IV. STATE OF MOTION OF THE HYDROGEN IONIZATION ZONE IN EARLY SPECTRAL TYPES. R.Kippenhahn.  
*Z. Astrophys. (Germany)*, Vol. 48, No. 3, 203-12 (1959). In German.  
 For Pt III, see Abstr. 2086 of 1960. From the current theory of zones of thermal instability, it is known that in early-type stars the hydrogen convection zone is very ineffective and the convection velocities are very small. It is shown that in this case the meridional circulation due to the rotation of a star produces turbulence with velocities of several km/sec in the region of thermal instability.

- 6720 NEW PLANETARY NEBULAE (P.N.) WITH TWO SHELLS. G.A.Gurzadyan.  
Dokl. Akad. Nauk SSSR, Vol. 133, No. 5, 1053-4 (Aug. 11, 1960). In Russian.  
For abstract, see Abstr. 18820 of 1960. [English translation in: Soviet Physics-Doklady (USA), Vol. 5, No. 4, 651-3 (Jan.-Feb., 1961)].

- 6721 A NEW CATALOGUE OF EMISSION-LINE STARS AND PLANETARY NEBULAE IN THE SMALL MAGELLANIC CLOUD. E.M.Lindsay.  
Astron. J. (USA), Vol. 66, No. 4, 169-85 (May, 1961).

The catalogue contains 593 point-source emission-line objects found mainly on 103a-E plates with red filter using the ADH telescope and objective prism. Blue and red photographic magnitudes and approximate positions have been measured. Thirty of the emission-line objects are considered to be planetary nebulae and 19 probably planetaries. Most of the remainder appear to be early type stars with a small mixture of red giants and supergiants. The mean absolute magnitudes and mean b-r colours are -4.3 and -0.69 for stars of negative b-r, -2.9 and +0.82 for stars of positive b-r and -2.7 and +0.70 for planetary nebulae. The bluest emission-line stars appear to be in the densest part of the cloud. The planetaries are most numerous in the southwest. The boundaries for emission-line objects in general and for clusters are very similar. The emission-line stars are found fairly uniformly throughout the main body of the cloud, along the tidal arm and out to the wing where they end.

- 6722 THE POSSIBILITY OF OBSERVING GASEOUS NEBULAE IN THE LYMAN  $\alpha$  LINE. G.A.Gurzadyan.  
Dokl. Akad. Nauk SSSR, Vol. 136, No. 5, 1055-8 (Feb. 11, 1961). In Russian.

Reasons why the diffuse component of  $L_{\alpha}$  radiation ( $L_{\alpha}$  noise) is virtually absent in the Galaxy are given. A small amount of direct  $L_{\alpha}$  radiation should therefore be observable against this silent background and the limiting brightness for which a celestial object is detectable (in  $L_{\alpha}$ ) is reduced significantly. Several applications are described: e.g. for sufficiently high radial velocities, a small part (about 1% at 50 km/sec and a distance of 100 ps) of the  $L_{\alpha}$  radiation emitted by a nebula should escape absorption by interstellar neutral hydrogen and reach the observer. The possibilities of observing in other lines of the Lyman series are briefly mentioned. [English translation in: Soviet Physics-Doklady (USA)]. G.A.Chisnall

- OPTICAL AND RADIO EMISSIONS OF THE CRAB NEBULA.  
See Abstr. 7068

- 6723 ESTIMATION OF THE DISPERSION OF THE REDSHIFT OF FIELD GALAXIES.  
J.Neyman and E.L.Scott.  
Astron. J. (USA), Vol. 66, No. 3, 148-55 (April, 1961).

The analysis of the joint distribution of distance, redshift, and apparent magnitude of field galaxies shows that, under certain conditions, the dispersion  $\sigma$  of redshift of field galaxies can be estimated empirically. This is possible by an indirect method, through the study of regression of certain functions of the redshift on the apparent magnitude. For example, the regression of the square of the redshift may be used for this purpose. The method has been applied to data published by Humason, Mayall, and Sandage. The estimate of the variance  $\sigma^2$  obtained is "negative zero", namely  $-(66 \text{ km/sec})^2$ , with an estimated standard error of  $(121 \text{ km/sec})^2$ . This result seems to indicate that the dispersion of redshift of field galaxies is small and, thus, the redshift of field galaxies is a reliable distance indicator.

- ELLIPSOIDAL GALAXIES. See Abstr. 6761

## Radioastronomy

- 6724 PROJECT WEST FORD — PROPERTIES AND ANALYSES. INTRODUCTION. L.Goldberg.  
Astron. J. (USA), Vol. 66, No. 3, 105-6 (April, 1961).

The proposal that one or more belts of thin microwave dipoles be placed into orbit about the earth at an altitude of a few thousand kilometres as a means for achieving a reliable system of long-range radio communication is discussed. See the three following abstracts.

- 6725 PROPERTIES OF ORBITING DIPOLE BELTS.  
W.E.Morrow, Jr and D.C.MacLellan.  
Astron. J. (USA), Vol. 66, No. 3, 107-13 (April, 1961).

See preceding abstract. The possible effects are examined of microwave dipole belts on radio communications, radar and measurements by optical and radio astronomers. In addition, a comparison is made of the probabilities of micrometeorite and dipole collisions with space craft. Calculations were carried out for a proposed experimental belt consisting of 35 kg of 8000 Mc/s dipoles orbiting at a few thousand kilometers altitude. It is shown that no interference would be caused to radio or radar services, that such a belt produces only a few per cent change in the optical brightness of the night sky in the direction of the belt, and that the influence of the belt on radio astronomy observations is not measurable except when viewing the belt where it is illuminated by very high power radio equipment operating at frequencies near the dipole resonance. Investigation also shown that micrometeorite collisions with a space craft located in a dipole belt are an order of magnitude more likely than those caused by the dipoles. Furthermore, the small mass of the dipoles limits the collision effects to little more than surface scratches.

- 6726 REPORT ON THE EFFECTS OF PROJECT WEST FORD ON OPTICAL ASTRONOMY. W.Liller.  
Astron. J. (USA), Vol. 66, No. 3, 114-16 (April, 1961).

This report is divided into three parts. The first summarizes the predictions of the effects of Project West Ford on optical astronomy, and includes comments by the author and others. The second contains recommended investigations which might be carried out before the launching date which would reduce some of the uncertainties mentioned. The third section described the observations which should be made of the orbiting dipoles by optical observatories the world over.

- 6727 RADIO PROPERTIES OF AN ORBITING SCATTERING MEDIUM. A.E.Lilley.  
Astron. J. (USA), Vol. 66, No. 3, 116-18 (April, 1961).

The future conduct of radio astronomical research is confronted with the consequences of an orbiting medium surrounding the earth. Deliberate and inadvertent radio transmissions will illuminate the medium, presenting new and variable artificial sources of radio noise to radio telescopic observation. Basic relationships are developed permitting an estimate of the apparent brightness temperature of the medium produced by terrestrial radio illumination. Provided with an assumption of the power, frequency and bandwidth of the transmitter, the cross-section of the orbiting medium, and the properties of the observing radio telescope, the resultant brightness temperature may be calculated. Consequences ranging beyond the production of artificial radio sources are considered. These include the attenuation of cosmic radio sources, space-probe radio emissions, and signal-to-noise ratios in space telecommunications systems. Based upon these considerations, the need for international protection of frequency bands for basic science is shown.

- 6728 FLARE-ASSOCIATED BURSTS AT 18 Mc/s.  
C.Warwick and J.W.Warwick.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1959 p. 203-7).

Only 18 Mc/s solar bursts associated with a flare were studied. These are compared with Type II and Type III bursts at higher frequencies. The correlation between the 18 Mc/s burst intensity and the importance of flares is not close and the 18 Mc/s bursts have no better indicators of geomagnetic activity than bursts at higher frequencies. R.D.Davis

- 6729 VARIATIONS IN 18 Mc/s SOLAR AND COSMIC NOISE.  
R.Fleischer.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1959 p. 208-9).

An interference rejecting circuit is used to measure the intensity of extraterrestrial radio emission. The solar origin of the bursts observed was confirmed by comparison with other received some thousands of miles distant. Cosmic noise was absorbed at 18 Mc/s during a flare of importance 2. R.D.Davis

- 6730 THE CORRELATION OF SOLAR RADIO BURSTS WITH MAGNETIC ACTIVITY AND COSMIC RAYS.  
A.R.Thompson.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1959 p. 210-13).

Type II solar bursts identified from swept-frequency records

ere followed 1.5 days later by an increase of the planetary K-index. preliminary study suggested that only the Type II bursts preceding are maximum gave rise to an increase in Kp. There was no increase in the cosmic-ray neutron count during times of noise storm or Type III burst activity, a fall in cosmic-ray intensity was often found.

R.D.Davies

6731 FLARE PUFFS AS A CAUSE OF TYPE III RADIO BURSTS. R.G.Giovanelli.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 214.

Only about 20% of all flares and microflares are associated with a Type III burst. However 67% of the flares accompanied by an initial sudden expansion visible as a bright "puff" are associated with Type III bursts.

R.D.Davies

6732 POLARIZATION OF BURSTS OF SOLAR RADIO EMISSION AT MICROWAVE FREQUENCIES.

(Tanaka and T.Kakinuma.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 215-17.

Observations of the degree of polarization of solar bursts were made at 1000, 2000, 3750 and 9400 Mc/s. At the lower frequencies the amount of circular polarization was generally small. No linear polarization was observed during 117 bursts at 3750 Mc/s. Sometimes the sense of circular polarization was different at different frequencies. At 9400 Mc/s the sense of polarization correlated with the position of the source on the sun as for the S-component.

R.D.Davies

6733 BURSTS OF MICROWAVE RADIO EMISSION ASSOCIATED WITH SOLAR FLARES. G.B.Gelfreich,

M.Ikhsanova, N.C.Kaidanovskii, N.S.Soboleva, G.M.Timofeeva, V.N.Umetski.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 218-21.

Nine bursts observed at a wavelength of 3.2 cm were studied. Seven were correlated with flares. The area of the burst region was similar to that of the flare area. All the observed data are tabulated.

R.D.Davies

6734 AN INTERFEROMETRIC STUDY OF ACTIVE SOLAR REGIONS AT 3 cm WAVELENGTH. M.R.Kundu.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p.222-36. In French.

Observations were made with an interferometer consisting of two aerials 60 m apart. The large bursts are only weakly polarized and they come from regions 2 minutes of arc in diameter. The active region remaining after the burst is strongly polarized for a long period.

R.D.Davies

6735 THE RELATION BETWEEN SOLAR COSMIC-RAY INCREASES AND CERTAIN RADIOFREQUENCY BURSTS. J.F.Denis.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 237-9. In French.

The increase in cosmic-ray intensity observed on 20 March 1958 was accompanied by bursts at 3 and 21 cm wavelength. The bursts lasted only about 20 seconds and were not visible at wavelengths longer than 60 cm. The diameter of the active region was much larger than is normally found for bursts. A bright filament occurred in the flare which was present at the time.

R.D.Davies

6736 INTERFEROMETRIC OBSERVATIONS AT 169 Mc/s OF R-REGIONS, THE SOURCES OF NOISE STORMS.

Avignon, A.Boischot and P.Simon.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 240-4. In French.

The observations were made with an interferometer having a beam 3.8' by 2° in the North-South line. R-regions show a activity such that the observed number of regions is halved at 75 radii from the centre of the solar disk. Their diameters may be as large as 10' and their heights lie in the range 0.3 to 1.0 solar radii. An R-region lasts typically 4 to 5 days.

R.D.Davies

6738 FREQUENCY DRIFT AND FINE STRUCTURE OF 200 Mc/s SOLAR BURSTS. Ø.Elgarøy.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 248-50.

Fine-structure bursts in noise storms were found to have an average duration of about 0.25 sec. The time between bursts was correlated with the duration of the bursts. Observations indicated that bursts in which the high frequencies occurred tended to be more common in the early stages of active regions and were rarer at later stages.

R.D.Davies

6737 SPECTRA OF SHORT-LIVED TRANSIENTS IN SOLAR NOISE AT 400 Mc/s. T.de Groot.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 245-7.

The duration of the bursts was 0.18 sec on average. Their bandwidths were about 6 Mc/s and frequency drift rates were generally greater than 500 Mc/s per sec.

R.D.Davies

6739 THE INSTANTANEOUS POSITION AND DIAMETER OF SHORT DURATION BURSTS OF SOLAR RADIO EMISSION. J.A.Högbom.

Radio Astronomy Symposium, Paris, 1958 (see Abstr. 10477 of 1960) p. 251.

Two interferometric systems at 3.7 m wavelength were used to show that for the noise storm of March 21 1958 the individual bursts had a diameter of  $6 \pm 1'$ . The scatter in position of the bursts was less than 3' and suggests that the large angular diameter may be due to scattering of the radiation during its passage through the corona.

R.D.Davies

6740 INDUCED CYCLOTRON MODEL OF NON-THERMAL SOLAR RADIO EMISSION. N.Hokkyo.

Publ. Astron. Soc. Japan, Vol. 12, No. 1, 28-41 (1960).

It is suggested that the various components of non-thermal solar radio spectrum in the metre wave range may be interpreted in terms of a single mechanism in which the radiation is emitted by electrons executing distorted helical motions around the magnetic lines of force under the combined action of the magnetic field and periodic electric fields associated with space-charge waves excited by the leading surge of corpuscular disturbances or shock waves moving through the solar atmosphere. The radiation contains generally both extraordinary and ordinary waves. The ordinary wave can escape through the solar atmosphere without a stopping region. On the other hand, it is shown that the extraordinary wave, which rotates in the same direction as the free cyclotron motion of electrons, may or may not escape the solar atmosphere depending on whether the solar atmosphere is disturbed by the corpuscular streams or not. The association of unpolarized bursts, type II or type III bursts, with corpuscular streams or shock waves may thus be understood. Polarized bursts, which do not show the frequency drift, will be emitted when corpuscular streams are ejected perpendicularly to the magnetic field whose strength is so large that the velocity of the associated Alfvén wave exceeds that of corpuscular disturbances. The observed intensity variation on single-frequency record of bursts may be interpreted in terms of successive formation and decay of plasma wave packet. The intensity of outbursts is reasonably accounted for by the induced cyclotron model.

6741 MICROWAVE BURSTS OF SOLAR RADIO EMISSION. T.Takakura.

Publ. Astron. Soc. Japan, Vol. 12, No. 1, 55-62 (1960).

Wide-band compound dynamic spectra of solar radio outbursts were studied in the frequency range from 9500 Mc/s to 67 Mc/s. The range of 9500-1000 Mc/s was covered by records at several fixed frequencies, and both the swept-frequency records and fixed-frequency records were used below 1000 Mc/s. A typical outstanding outburst may be as follows. A short-lived burst whose duration is several minutes begins almost simultaneously at frequencies above 1000 Mc/s. The flux density of the burst is maximum at about 9000 Mc/s-3000 Mc/s, decreases with decreasing frequency and is generally very weak below 1000 Mc/s. A few minutes later, a type II burst begins in the metre wave region with a sharp high-frequency cut-off which is usually below 350 Mc/s for the fundamental wave (and below 700 Mc/s for the second harmonic). Following the type II burst, a broad-band type IV burst begins and lasts one hour or two. The frequencies of the maximum flux density of the type IV bursts vary from 200 Mc/s to 10000 Mc/s. The short-lived burst at frequencies above 1000 Mc/s is neither an extension of the type II burst nor the same as the type IV burst. It is a distinctive type of

burst and may be called "microwave burst" or "M-type" burst. According to the current classification of microwave bursts, short-lived SD (simple and distinct) and CD (complex and distinct) bursts whose durations are less than about 10 minutes seem to be "M-type" bursts, while long-lived CD bursts might be type IV bursts.

6742 UNUSUAL DECREASE OF MICROWAVE SOLAR RADIO EMISSION DURING FLARE ON NOVEMBER 30, 1959.

T. Kakinuma and E. Hiei.

Publ. Astron. Soc. Japan, Vol. 12, No. 1, 117-23 (1960).

An unusual decrease of microwave solar radio emission observed in Japan on November 30, 1959 is reported, together with the optical observations of the associated flare.

6743 SOLAR RADIO BURSTS AND COSMIC RAYS.

A.R. Thompson and A. Maxwell.

Planet. Space Sci. (GB), Vol. 2, No. 2-3, 104-9 (April, 1960).

Current theories of the origin of solar radio bursts suggest that fast drift (Type III) bursts may be generated by the emission of solar particles with velocities approaching those of cosmic rays. An examination of cosmic ray intensity and solar radio data over the two-year period 1956 October-1958 September shows, however, no correlation between fast drift bursts and cosmic ray increases on the earth. Solar flares, with which fast drift bursts are associated, also appear to be unrelated to cosmic ray increases. On the other hand there have been a number of cases of increases in low energy cosmic ray particles, recorded by equipment in satellites and balloons, which were probably related to outbursts of solar continuum (Type IV) radiation. Forbush type decreases in cosmic ray intensity, and accompanying magnetic storms, are regularly preceded by slow drift (Type II) radio bursts.

6744 THE METEORIC HEAD ECHO.

A.F. Cook and G.S. Hawkins.

Smithsonian Contrib. Astrophys. (USA), Vol. 5, No. 1, 1-7 (1960).

The hypothesis is examined that the meteoric head echo is due to ultraviolet ionizing radiation from the meteor, and the subsequent dissociative recombination of the molecular ions and electrons produced. It is shown that molecular oxygen is probably the ionized constituent. The hypothesis is examined quantitatively and a recombination coefficient of approximately  $2 \times 10^{-5} \text{ cm}^3 \text{ sec}^{-1}$  for molecular oxygen ions is deduced.

## Space Research

INTERIM ATMOSPHERE DERIVED FROM ROCKET AND SATELLITE DATA. See Abstr. 6601

6745 THE APPLICATION OF PERIODIC SURFACE THEORY TO THE STUDY OF SATELLITE ORBITS.

S.P. Diliberto, W.T. Kyner and R.B. Freund.

Astron. J. (USA), Vol. 66, No. 3, 118-28 (April, 1961).

This paper contains results on the application of the theory of periodic surfaces to the problem of determining the drag free orbits of satellites around an oblate earth. This theory employs a description of solutions which involves two distinct parts: One element describes a surface on which solutions travel and the second element describes the solutions on that surface. The formulae giving the approximate solutions were tested numerically and the results included in the paper.

6746 ON SATELLITE ORBITS WITH VERY SMALL ECCENTRICITIES.

I.G. Izsak.

Astron. J. (USA), Vol. 66, No. 3, 129-31 (April, 1961).

On the basis of a theory developed previously (Abstr. 18881 of 1960), satellite orbits with very small eccentricities were investigated. It was found that such orbits can be represented by a simple formula. Graphical illustrations of this result are given.

6747 NOTE ON THE MOTION OF A CLOSE EARTH SATELLITE WITH A SMALL ECCENTRICITY.

Y. Kozai.

Astron. J. (USA), Vol. 66, No. 3, 132-4 (April, 1961).

In the expressions of the argument of perigee  $\omega$  and the mean anomaly  $M$ , derived in a previous paper on the motion of a close earth satellite (Abstr. 5340 of 1959), there is a divisor  $e$ , the eccentricity. If the eccentricity is very small, the amplitudes in these expressions become so large that they cannot be regarded as perturbations. The present paper proves that when the three elements

$e \cos \omega$ ,  $-e \sin \omega$ , and  $M + \omega$  are used instead of  $e$ ,  $\omega$ , and  $M$ , the expressions of the radius and the argument of latitude are the same for both the typical and the small eccentricities.

6748 ON THE ALMOST PERIODICITY OF SATELLITE MOTION.

E.D. Callender.

Astron. J. (USA), Vol. 66, No. 3, 134-7 (April, 1961).

Using the Vinti model for an oblate earth it is possible to show that for small values of the oblateness parameters the motion of a near satellite is almost periodic. To prove this result, bounds on the variation of the radial distance and the variation of the angle of inclination are obtained.

6749 DETERMINATION OF THE OSCULATORY ELEMENTS OF THE ORBIT OF AN ARTIFICIAL SATELLITE.

J. Kovalevsky and F. Barlier.

C.R. Acad. Sci. (France), Vol. 252, No. 9, 1273-5 (Feb. 27, 1961). In French.

This note gives a variation on the method of Laplace for the determination of the orbit of a planet, comet or artificial satellite from observations of a small arc of its path. The method described obtains greater precision in the initial determination of the angular coordinates, and their first and second derivatives, by considering derivatives up to the fifth order, and calculating them by a least-squares method from as many observations as are available. The orbit is then adjusted to fit the observations by a method of variations, but working in Cartesian rather than polar coordinates. This gives a rapid convergence, two iterations have often been found sufficient.

H. Morrice

6750 SATELLITE ORBITS AND ATMOSPHERIC DENSITIES AT ALTITUDES UP TO 750 km OBTAINED FROM THE VANGUARD ORBIT DETERMINATION PROGRAM.

J.W. Siry.

Planet. Space Sci. (GB), Vol. 1, No. 3, 184-92 (Aug., 1959).

6751 SOME DYNAMICAL PROPERTIES OF NATURAL AND ARTIFICIAL SATELLITES.

Su-Shu Huang.

Astron. J. (USA), Vol. 66, No. 4, 157-9 (May, 1961).

Some qualitative properties of natural and artificial satellites in the solar system that can be understood in terms of the restricted three-body problem are discussed here.

6752 METHODS OF PHOTOGRAPHIC OBSERVATION OF ARTIFICIAL SATELLITES AT MEUDON OBSERVATORY.

P. Muller and F. Barlier.

C.R. Acad. Sci. (France), Vol. 251, No. 25, 2886-8 (Dec. 19, 1960). In French.

Details are given of the procedure adopted at Meudon for inscribing time marks on the photographic track of a satellite, and the manner in which the records are reduced to give the coordinates of the satellite.

G.M. Brown

6753 THE APPLICATION OF RAY TRACING METHODS TO RADIO SIGNALS FROM SATELLITES.

I.N. Capon.

Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 337-45 (Feb., 1961).

A method of calculating the effect that an ionosphere of given form will have on a radio signal emitted by an earth satellite is described. The method is based on ray tracing techniques, involving the integration of a system of differential equations. Results of high accuracy may be obtained. Some results obtained with an ionospheric model in which the electron density increases linearly up to the F2 peak, and the decays according to the Chapman law, are presented and discussed. These results relate to the received characteristics of the signal, including the Doppler shift, the Faraday effect and the refraction. One of the models considered varies slowly with latitude, and this has a marked effect on the results. The effect of a 10% change in scale height is also shown, and is much smaller than that due to an ionospheric slope.

6754 IRREGULAR FADING OF SATELLITE TRANSMISSIONS.

W.C. Bain.

Nature (GB), Vol. 189, 129 (Jan. 14, 1961).

Irregular fluctuations were observed in the signal strength of the 20 Mc/s transmissions from Explorer 7. The scintillation decreases as the satellite moves away from magnetic north. The decrease is not so sharp and does not continue to such a low level as that found by others for the 40 Mc/s transmissions from Sputnik.

C. Hazen

EXPLORER I INSTRUMENTATION FOR METEORITIC DUST MEASUREMENTS. See Abstr. 6706

## PHYSICS

## GENERAL

## GRAVITATION . RELATIVITY

6755 THE ANNUAL EXHIBITION OF THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY - LONDON  
1961. A.M.Taylor.

J. sci. Instrum. (GB), Vol. 38, No. 5, 173-7 (May, 1961).

Review article.

6756 PHYSICS AND ARCHAEOLOGY.  
M.J.Aitken.

New York, London: Interscience Publishers (1961) x + 181 pp.

The book is intended both for the general scientific reader and for the student of "archaeometry". With the latter in view, copious references are included at the end of each chapter. The chapters are listed as follows: (1) Finding, (2) Magnetic Location, (3) The Proton Magnetometer, (4) Resistivity Surveying, (5) Dating, (6) Radio-carbon Dating, (7) Magnetic Dating, and (8) Analysis. There are both author and subject indexes.

6757 BIBLIOGRAPHY OF INTERLINGUAL SCIENTIFIC AND TECHNICAL DICTIONARIES [FOURTH EDITION].  
Paris: Unesco (1961) xxxiv + 236 pp.

The bibliography is the most comprehensive work in this field. The dictionaries are grouped by subject in accordance with the Universal Decimal Classification. There are language, author and subject indexes. The subject index and introductory matter are given in English, French and Spanish.

6758 LEV DAVYDOVICH LANDAU. WINNER OF THE SECOND FRITZ LONDON AWARD. J.R.Pellam.

Phys. Today (USA), Vol. 14, No. 3, 42-7 (March, 1961).

An address presented at the 7th International Conference on Low Temperature Physics (Toronto, 29 Aug. to 30 Sept., 1960) on the occasion of the 2nd Fritz London Award ceremony. Dr. Landau was unable to attend.

6759 ABRAM FEDOROVICH IOFFE (ON HIS EIGHTIETH BIRTHDAY). I.K.Kikoin and M.S.Sominskii.

Uspekhi fiz. Nauk (USSR), Vol. 72, No. 2, 307-21 (Oct., 1960). In Russian.

An appreciation of Ioffe's contributions to physics and of his influence on the development of the physical sciences in the U.S.S.R. The bibliography comprises 52 of his main works. [Ioffe died on 4 October 1960, just before his eightieth birthday]. [English translation in: Soviet Physics—Uspekhi (USA), Vol. 3, No. 5, 798-809 (March-April, 1961)].

6760 THE INTERPRETATION OF MEASUREMENTS BY THE REGULARITY CONDITION. P.Vernotte.  
C.R. Acad. Sci. (France), Vol. 251, No. 22, 2486-8 (Nov. 28, 1960). In French.

The principle of regularity utilizes the simplicity of the distribution of signs in a table of successive derivatives (at equal intervals of the independent variable) to correct experimental data to obtain the best functional relationship between the variables. A methodical procedure is indicated for finding the corrections when the experimental function is decreasing and when the data is limited to a small number of items.

G.A.Chisnall

6761 ELLIPSOIDAL DISTRIBUTIONS OF CHARGE OR MASS.  
B.C.Carlson.

J. math. Phys. (USA), Vol. 2, No. 3, 441-50 (May-June, 1961).

The Coulomb (or gravitational) energy is calculated for a distribution of charge (or mass) in which the surfaces of constant density are a family of similar concentric ellipsoids. The density can vary in any manner from one surface to another, and the ellipsoids need not have an axis of symmetry. Two examples are discussed: the charge distribution of a deformed atomic nucleus having a diffuse surface, and the mass distribution of a stellar galaxy. The energy is shown to be a product of two factors. One is the energy of the spherical distribution from which the ellipsoidal distribution can be obtained by a volume-preserving deformation. The other is an anisotropy factor that has a simple geometrical significance and depends only on the two eccentricities of the ellipsoids. Its values range from unity to zero and are tabulated numerically.

6762 QUANTIZATION ON A RIEMANNIAN MANIFOLD.  
A.Capella.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 240-2 (Jan. 9, 1961). In French.

Commutation relations for variations in the vacuum metric tensor and vacuum Riemann tensor are written down, using the author's quantization method (Abstr. 10586 of 1960) in terms of Lichnerowicz's propagators (Abstr. 10563 of 1960). Lichnerowicz's quantization of the linear approximation is obtained as a special case.

F.A.E.Pirani

6763 SOME PROPERTIES OF EMPTY SPACE—TIME.  
E.Newman.

J. math. Phys. (USA), Vol. 2, No. 3, 324-7 (May-June, 1961).

In close analogy to the "vierbein" technique of representing world vectors as linear combinations of four fixed vectors, constructed from six linearly independent bivectors a (complete) set, or basis, of ten tensors of rank 4 that possess all the algebraic properties of the empty-space Riemann-Christoffel tensor (i.e. Weyl's tensor). Any actual Weyl tensor must be a linear combination of these ten; the expansion coefficients with respect to a given basis are uniquely determined. Petrov's classification scheme is examined in terms of this formalism and a further division into subclasses is developed. Finally, as an application of the new technique, the derivation of plane-fronted waves, is presented.

6764 SOME APPLICATIONS OF THE INFINITESIMAL-HOLONOMY GROUP TO THE PETROV CLASSIFICATION OF EINSTEIN SPACES. J.N.Goldberg and R.P.Kerr.  
J. math. Phys. (USA), Vol. 2, No. 3, 327-32 (May-June, 1961).

The classifications of Einstein spaces by Schell (1961) and Petrov (1954) are combined and certain nonlocal results are obtained. In particular, it is shown that an Einstein space cannot be type I with a rank-four Riemann tensor in a four-dimensional region. On using the notion of a perfect or imperfect infinitesimal-holonomy group, the conditions are established under which an Einstein space possesses a two-, four-, or six-parameter group. It is found that two- and four-parameter groups are associated with special cases of type II null and type III, respectively.

6765 EINSTEIN SPACES WITH FOUR-PARAMETER HOLONOMY GROUPS. R.P.Kerr and J.N.Goldberg.  
J. math. Phys. (USA), Vol. 2, No. 3, 332-6 (May-June, 1961).

The metric tensor is constructed for Einstein spaces which are Petrov type III and whose holonomy group is four-parametric. Together with the previously known plane-fronted wave solutions, this completes the study of all metrics whose holonomy groups are less than six parameter. The Killing vector equations are studied and it is found that the space cannot admit more than two independent motions.

6766 METHODS FOR QUANTIZATION OF THE GRAVITATIONAL FIELD. P.Droz-Vincent.

Cahiers de Phys. (France), Vol. 14, 279-84 (July, 1960). In French.

Brief expositions, without criticism, of the approaches to quantization of Arnowitz, Deser and Misner (Abstr. 6660 of 1960) and Bergmann and Komar (Abstr. 10578 of 1960) as reported at the Royaumont Conference on Gravitation, June 1959.

F.A.E.Pirani

6767 PLANCK'S CONSTANT AS THE SQUARE OF THE GRAVITATIONAL CHARGE. O.Costa de Beauregard.  
C.R. Acad. Sci. (France), Vol. 252, No. 6, 849-51 (Feb. 6, 1961). In French.

It is noted that, in the interaction Lagrangian for spin and gravitational fields, the quantity  $\hbar c$  plays a role analogous to that of the square of a charge in electromagnetic theory. The quantity  $\sqrt{\hbar c/G}$  is proposed as a "universal gravitational charge", and is related to the author's suggestion of "strong" gravitational forces and to existence of a fundamental length.

R.A.Newing

6768 THE RELATIVISTIC KINETIC EQUATION AND THE EQUILIBRIUM STATE OF A GAS IN A STATIC SPHERICALLY-SYMMETRIC GRAVITATIONAL FIELD.

N.A.Chernikov.

Dokl. Akad. Nauk SSSR, Vol. 133, No. 2, 333-6 (July 11, 1960). In Russian.

For abstract, see Abstr. 14496 of 1960. [English translation in: Soviet Physics-Doklady (USA), Vol. 5, No. 4, 786-9 (Jan.-Feb., 1961)].

6769 NOTE ON THE MODIFIED GRAVITATIONAL EQUATIONS  $g^2 R_{ik} = 0$ . D.M.Lipkin.

Phys. Rev. (USA), Vol. 122, No. 3, 972 (May 1, 1961).

The single example of a gravitational manifold which Einstein and Rosen presented (Abstr. 3322 of 1935) in support of their modified field equations  $g^2 R_{ik} = 0$  is shown to satisfy uniformly the unmodified field equations  $R_{ik} = 0$  and hence to provide insufficient logical support for their proposed modification. The demonstration is made in the original coordinates used by Einstein and Rosen, by direct calculation of the curvature tensor of the manifold.

6770 NEWTONIAN AND GALILEAN REFERENCE FRAMES (OF THE SPECIAL THEORY OF RELATIVITY) DEFINED AND COMPARED BY ELEMENTARY MATHEMATICS.

C.J.Wolfson.

Proc. Iowa Acad. Sci. (USA), Vol. 67, 394-8 (1960).

The stated reference systems are mathematically defined using three dimensional Cartesian coordinates and sets of functions, and then systematically developed and contrasted. The linearity of the Lorentz transformation equations for special relativity is shown to follow directly from the definition of a Galilean inertial reference system.

6771 ON THE CALCULATION OF THE CURVATURE TENSOR IN THE FIRST RELATIVISTIC APPROXIMATION. A.R.Gomes.

C.R. Acad. Sci. (France), Vol. 251, No. 19, 1978-80 (Nov. 7, 1960). In French.

In the first approximation to the solution of the field equations for a universe filled with a perfect fluid of velocity  $u^\alpha$ , the four "projection tensors" (e.g.  $Y_{\alpha\lambda} = R_{\alpha\beta\lambda\mu} U^\beta U^\mu$  and similar expressions with the duals of the curvature tensor) are calculated.

C.W.Kilmister

6772 STATES OF PURE RADIATION IN GENERAL RELATIVITY. J.Hély.

C.R. Acad. Sci. (France), Vol. 251, No. 19, 1981-2 (Nov. 7, 1960). In French.

Let  $I, J, K, L$  be four linear homogeneous functions of the coordinates, and let

$$g_{\alpha\beta} = \delta_{\alpha\beta} + l_\alpha u_\beta + l_\beta u_\alpha,$$

where  $u_\alpha = a l_\alpha + \partial_\alpha b + (I_\alpha J - J_\alpha I) f_0$ ,

and  $a = l_y f_y b + f_y x y + F(I, J, L)$ ,

where  $I_\alpha = \frac{\partial I}{\partial x^\alpha}$ ,  $l_\alpha = \frac{\partial l}{\partial x^\alpha}$ , etc, and  $b$  is

any function of the coordinates. If the four functions satisfy some conditions of orthogonality with respect to the  $\delta_{\alpha\beta}$  metric, the curvature tensor becomes

$$R_{\alpha\beta\lambda\mu} = (l_\alpha \partial_\beta - l_\beta \partial_\alpha)(l_\lambda \partial_\mu - l_\mu \partial_\lambda)(F + l_y J_y f_0^2 IJ)$$

where  $l_y l_y = \sum_y l_y l_y$ .

This form is used to discuss radiation.

C.W.Kilmister

6773 EXPLICIT SOLUTION OF THE INHOMOGENEOUS TRANSPORT EQUATIONS IN A MODIFIED VERSION OF EINSTEIN'S THEORY. J.Lévy.

C.R. Acad. Sci. (France), Vol. 251, No. 20, 2129-31 (Nov. 14, 1960). In French.

The equations  $g_{\mu\nu} p_\nu = A_{\mu\nu} p_\nu$  of the author's unified theory

(Abstr. 18933 of 1960) are solved algebraically for the connection quantities.

F.A.E.Pirani

6774 A SOLUTION OF GEODESICAL LINES EQUATIONS. A.Anastasov.

C.R. Acad. Bulg. Sci., Vol. 13, No. 6, 665-8 (Nov.-Dec., 1960).

Certain results are stated about geodesics in a static space-time

with an orthogonal coordinate-system. They appear to the reviewer to be incorrect, except under the restrictive condition that the remaining components of the metric are functions of one coordinate only.

C.W.Kilmister

6775 NONLINEAR ELECTRODYNAMICS IN GENERAL RELATIVITY. A.Peres.

Phys. Rev. (USA), Vol. 122, No. 1, 273-4 (April 1, 1961).

General relativistic field equations are derived from a gauge invariant electromagnetic Lagrangian, which does not involve derivatives of the field, nor any charge density, but otherwise is completely arbitrary. These equations are explicitly solved in the static spherically symmetric case, and it is shown that there are solutions which are everywhere regular and behave, at large distances, like the gravitational and electromagnetic fields of a point charge. Some wave-like solutions are also derived.

6776 WAVE FRONTS IN EINSTEIN'S UNIFIED THEORY. L.Mas and A.Montserrat.

C.R. Acad. Sci. (France), Vol. 252, No. 3, 382-4 (Jan. 16, 1961). In French.

A Riemannian connection associated with the symmetric part of the metric tensor is introduced, and the methods of Lichnerowicz are used to study discontinuities of the corresponding curvature tensor.

R.A.New

6777 WAVE-FRONTS IN THE EINSTEIN UNIFIED FIELD THEORY: THE CASE OF A MAURER-TISON CHARACTERISTIC SURFACE. A.Montserrat and L.Mas.

C.R. Acad. Sci. (France), Vol. 252, No. 8, 1110-12 (Feb. 20, 1961). In French.

The discontinuities in the curvature tensor consequent on crossing a characteristic surface (tangent everywhere to the cone  $h_{\alpha\beta} l^\alpha l^\beta = 0$ , where  $h_{\alpha\beta}$  is the symmetric part of  $g_{\alpha\beta}$ ) are studied introducing a Riemannian connection, i.e.  $\Gamma_{\beta\gamma}^\alpha$  such that  $h_{\alpha\beta,\gamma} - \Gamma_{\alpha\gamma}^\rho h_{\rho\beta} - \Gamma_{\beta\gamma}^\rho h_{\alpha\rho} = 0$ .

C.W.Kilmister

6778 THE EQUATIONS OF MOTION IN UNIFIED FIELD THEORY. M.Lenoir.

Cahiers de Phys. (France), Vol. 14, 331-9 (Aug., 1960). In French.

A critical review of various attempts that have been made to derive the equations of motion of a test particle from the field equations in the Einstein-Schrödinger unified theory.

R.A.New

## QUANTUM THEORY

(Applications of quantum theory to elementary particles and nuclei are included under Nuclear Field Theory)

6779 INTRODUCTION TO QUANTUM MECHANICS. R.H.Dicke and J.P.Wittke.

Reading (Massachusetts), London: Addison-Wesley Publishing Co. (1960) xi + 369 pp.

A text-book of honours degree standard whose scope has been deliberately limited to nonrelativistic theory. The opening chapter point out the inadequacy of classical concepts to explain many atomic-scale phenomena and suggest how the basic concepts of classical mechanics must be altered to explain experimental observations. The second section of the book (Chapters 4-10) consist of a formal approach to quantum mechanics. The final section (Chapters 11-18) represent a broadening of the viewpoint of the scope of the problems that can be handled and alternative methods of treatment are presented. The final chapter is devoted to quantum-statistical mechanics. Problems are provided at the end of most chapters and there is an adequate index.

6780 ON THE ACCURACY IN THE APPROXIMATE CALCULATION OF ENERGY LEVELS.

F.Combet-Farnoux and G.Allard.

C.R. Acad. Sci. (France), Vol. 252, No. 7, 999-1001 (Feb. 13, 1961). In French.

The authors derive inequalities, some of them new, relating to the expansion of a stationary state in terms of a given complete set.

R.J.N.Phillips

6781 THE WAVES ASSOCIATED WITH THE INTERNAL STRUCTURE OF PARTICLES. NON-RELATIVISTIC APPROXIMATION. P.Hillion and J.P.Vigier. *Cahiers de Phys. (France)*, Vol. 14, 345-78 (Sept., 1960). In French. The properties are established of a quantum mechanics invariant under the group  $R_3$  of real rotations in three dimensions. The wave functions corresponding to the finite representations of  $R_3$  are discussed, and the equations which they satisfy derived. The associated Lagrangian and Hamiltonian formalisms are treated. A pseudo-vector is obtained having the properties of spin (as deduced from Pauli's equation). A relation is obtained between the charge operator, arising from the invariance of the theory under the one-parameter gauge group, and certain differential operators, which may be considered as a non-relativistic analogue of the formulae of Gell-Mann and Nishijima. J.E.Paton

ON THE TRANSVERSE SHIFT [ASSOCIATED] WITH THE TOTAL REFLECTION OF MATTER WAVES. See Abstr. 6924

6782 RELATION OF PERTURBATION THEORY TO VARIATION METHOD. O.Sinanoğlu. *J. chem. Phys. (USA)*, Vol. 34, No. 4, 1237-40 (April, 1961). The various order wave-functions of the Rayleigh-Schrödinger perturbation theory can be obtained directly by solving certain differential equations or by minimizing equivalent variational expressions. These expressions are related to the ordinary variation method. The perturbation series is shown to result in a unique way from the minimization of larger and larger portions of  $\langle \psi, H \psi \rangle / \langle \psi, \psi \rangle$ . In addition to several orders of perturbation, each step gives the exact remainders and upper limits to the energy. The approach suggests several "variation-perturbation" schemes.

6783 TRANSLATIONALLY INVARIANT OSCILLATOR POTENTIAL. G.Lüders. *Z. Naturforsch. (Germany)*, Vol. 16a, No. 1, 76-8 (Jan., 1961). In German.

Discusses the quantum-mechanical problem of  $N$  identical particles moving in a translationally invariant oscillator potential. Use is made of the close connection of this problem with the one where the potential is fixed in space. In particular, relations are given between the number of states of prescribed permutational symmetry (and orbital angular momentum) and of fixed energy, in the two problems.

6784 WIGNER COEFFICIENTS FOR THE  $R_4$  GROUP AND SOME APPLICATIONS. L.C.Biedenharn. *J. math. Phys. (USA)*, Vol. 2, No. 3, 433-41 (May-June, 1961). The four-dimensional rotation group ( $R_4$ ) is of intrinsic general interest for applications in physics, but it is of special interest for applications to (nonrelativistic) physical problems concerned with the Coulomb field. The local isomorphism of the  $R_4$  group to the group  $R_3 \times R_3$  is utilized to obtain  $R_4$  Wigner coefficients for those representations in which the subgroup  $R_3$  is diagonal. The  $R_4$  Wigner coefficients so defined are then used to obtain recursion relations and differential equations for the representation coefficients, when the group is parametrized appropriately. The  $R_4$  spherical harmonics, and their properties, are explicitly obtained as specializations of the general formulae. Physical application to the problem of geometrizing the Coulomb field is briefly discussed.

QUANTIZATION ON A RIEMANNIAN MANIFOLD. See Abstr. 6762

METHODS FOR QUANTIZATION OF THE GRAVITATIONAL FIELD. See Abstr. 6766

6785 ORTHOGONAL SETS OF EIGENFUNCTIONS WITH DEFINITE SYMMETRY FOR THE WAVE-FUNCTIONS OF A SYSTEM OF THREE IDENTICAL PARTICLES. J.Munsch, P.Pluvineau and J.Proriol. *J. Phys. Radium (France)*, Vol. 21, No. 2, 85-93 (Feb., 1960). In French.

As a first step in the precise study of the quantum radial problem for a system of three identical particles, a method of building orthogonal sets of eigenfunctions with definite character of symmetry is given. Rather than the three linear distances of the particles, three variables more closely related to a representation of the symmetric group  $S_3$  are chosen. The first is not affected by permutations. The two others are transformed in a simple way, and it is possible to form with them polynomials of definite symmetry. These polynomials are determined as eigenfunctions of two commutable operators. Explicit expressions are given up to the fifth degree, which is sufficient for practical purposes.

BROWNIAN MOTION OF A QUANTUM OSCILLATOR. See Abstr. 6787

## STATISTICAL MECHANICS TRANSFER PROCESSES

6786 STATISTICAL DYNAMICS OF SIMPLE CUBIC LATTICES. MODEL FOR THE STUDY OF BROWNIAN MOTION. II. R.J.Rubin. *J. math. Phys. (USA)*, Vol. 2, No. 3, 373-86 (May-June, 1961).

For Pt I see Abstr. 17876 of 1960. New results concerning the statistical dynamics of a heavy particle in an  $n$ -dimensional ( $nD$ ) cubic lattice are presented. It is demonstrated that this model exhibits many properties which are familiar in the phenomenological theory of Brownian motion. In a well-defined sense, the random thermal motions of a heavy particle in a 1D lattice and 3D lattice are accurately described by Kramers' equation for a free particle and a harmonically bound particle, respectively. A related, but not independent, result is that the velocity  $v(t)$  and position  $u(t)$  of a heavy particle in a 1D lattice and a 3D lattice constitute two-dimensional stationary Gaussian Markoff processes. It is definitely established that in the case of a 2D lattice the stationary Gaussian process  $\{v(t), u(t)\}$  is non-Markoffian. In the course of the analysis, several interesting connections between solutions of the discrete lattice equations of motion and solutions of the corresponding continuum equation of motion (the  $nD$  wave equation) are uncovered.

6787 BROWNIAN MOTION OF A QUANTUM OSCILLATOR. J.Schwinger. *J. math. Phys. (USA)*, Vol. 2, No. 3, 407-32 (May-June, 1961).

A quantum action principle technique for the direct computation of expectation values is described and illustrated in detail by a special physical example, the effect on an oscillator of another physical system. This simple problem has the advantage of combining immediate physical applicability (e.g. resistive damping or maser amplification of a single electromagnetic cavity mode) with a significant idealization of the complex problems encountered in many-particle and relativistic field theory. Successive sections contain discussions of the oscillator subjected to external forces, the oscillator loosely coupled to the external system, an improved treatment of this problem and, finally, there is a brief account of a general formulation.

6788 BROWNIAN MOVEMENT OF A QUANTUM OSCILLATOR. C.George. *Physica (Netherlands)*, Vol. 26, No. 7, 453-77 (July, 1960). In French.

The statistical theory of irreversible processes, developed by Prigogine and his co-workers, is applied to the study of the Brownian motion of a quantum linear harmonic oscillator weakly coupled with a thermostat. It is shown that the evolution process is Markoffian, and that, in the limit of long times, the expected equilibrium distribution is reached. The behaviour of the Wigner function is studied, and a method is indicated for calculating the mean values of all the powers of the velocity and the displacement, in terms of the corresponding classical mean values.

6789 MASTER EQUATION SOLUTION OF ORNSTEIN-UHLENBECK PROCESSES. J.I.Bowen and P.H.E.Meijer. *Physica (Netherlands)*, Vol. 26, No. 7, 485-91 (July, 1960).

The continuous master equation is solved in closed form for transition probabilities which are Gaussian and assuming the equilibrium solution to be Gaussian (i.e., the equilibrium fluctuations are Gaussian processes). In this case, the eigenfunctions of the integral equation obtained after the kernel is symmetrized are merely Hermite functions and the eigenvalues are related to one another as successive integer powers of a constant  $\mu_n = \rho^n$ . The constant  $\rho$  is the correlation coefficient for the (stationary) equilibrium process, over the unit time in which the transition probabilities are expressed. The complete (time-dependent) solution for the probability density function is an infinite series of Hermite-type functions, each modified by a term decaying in time. For these Ornstein-Uhlenbeck processes, the relaxation times decrease inversely proportional to the order of the term. The time dependent moments of the distribution of order  $n$  can be simply calculated from a knowledge of not more than  $(n+1)/2$  moments of lower order of the initial distribution. Several examples of different initial distributions are given.

6790 ESTIMATION OF DOPPLER SHIFTS IN NOISE SPECTRA. P.Swerling.  
IRE internat. Convention Record (USA), Vol. 8, No. 4, 148-52 (1960).  
A sample function  $N(t)$  of a stationary Gaussian random process  $\{N(t)\}$ , having zero mean, is observed for a finite length of time. The power spectrum of  $\{N(t)\}$  is assumed to belong to a family of functions  $\{F_h(\omega)\}$ , where  $F_h(\omega) = F[\omega(1+h)]$ , and  $F(\omega)$  is a completely specified even, non-negative, square integrable function of  $\omega$ . The problem is to estimate  $h$ . Formulae are derived for the mean and variance of estimates belonging to a certain class of estimates of  $h$ . Modifications of these formulae are given for the case where the spectrum shape  $F(\omega)$  is imperfectly known. An illustrative numerical example is given. A possible application to space-flight navigation is pointed out.

6791 ON THE EQUIVALENCE OF INFORMATION AND ENTROPY IN THE RATIO  $1/(k \ln 2)$ .  
O.Costa de Beauregard.  
C.R.Acad. Sci. (France), Vol. 251, No. 25, 2898-2900 (Dec. 19, 1960). In French.  
By analogy with the fact that, in "anthropomorphic" (c.g.s) units,  $c$  is very large and  $h$  is very small, it is argued that the smallness of the conversion factor  $k \ln 2$  masks a real symmetry in the relation between entropy and information, making it appear "expensive" to convert information into action decreasing entropy (Maxwell's demon, etc). J.Hawgood

6792 EQUIVALENCE OF THE BAYES PRINCIPLE, THE PRINCIPLE OF INCREASING ENTROPY AND THE PRINCIPLE OF RETARDED QUANTIZED WAVES.  
O.Costa de Beauregard.  
C.R. Acad. Sci. (France), Vol. 251, No. 22, 2484-5 (Nov. 28, 1960). In French.  
Discussion of macroscopic irreversibility, and the lack of symmetry between prediction and retrodiction, in terms of these three principles, which are shown to lead to similar conclusions. J.Hawgood

6793 APPROACH TO THERMODYNAMIC EQUILIBRIUM.  
J.E.Mayer.  
J. chem. Phys. (USA), Vol. 34, No. 4, 1207-23 (April, 1961).  
The properties of a macroscopic classical system consisting of some  $10^{20}$  molecules are determined by a probability density function  $W$  of the complete  $\Gamma$  space of moments and coordinates of all the molecules. This probability density function is that of the ensemble representing the totality of all experimental systems prepared according to the macroscopic specifications. The entropy is always to be defined as the negative of  $k$  times the integral over the distinguishable phase space of  $W \ln W$ . However, the total probability density function  $W$ , even for a thermodynamically isolated system, does not obey the Liouville equation,  $\partial W / \partial t = LW$ , since small fluctuations due to its contact with the rest of the universe necessarily "smoothes"  $W$ , by smoothing the direct many body correlations in its logarithm. This smoothing is the cause of the entropy increase, and in systems near room temperature and above, in which there is heat conduction or chemical species diffusion, the smoothing keeps the true entropy numerically equal to that inferred from the local temperatures, pressures, and compositions. This, however, is by no means necessarily general. The criterion of thermodynamic isolation is not that the complete probability density function  $W$  is unaffected by the surroundings, but that reduced probability density functions  $w_n$  in the  $\Gamma$  space of  $n = 2, 3, \dots$  molecules evolve in time as if the system were unaffected by the surroundings. This criterion is sufficient to give a mathematically definable method of "smoothing" the complete probability density function. The smoothing consists of replacing the direct many-body correlations in  $\ln W$  by their average  $n$  body values,  $n = 2, 3, \dots$  such that the smaller reduced probability density functions  $w_n$  are unaffected.

6794 THE NONCONSTANCY OF THE ADIABATIC INVARIANTS. P.O.Vandervoort.  
Ann. Phys. (USA), Vol. 12, No. 3, 436-43 (March, 1961).  
The change in the adiabatic invariant (action integral) of a one-dimensional system is investigated in the case that an external parameter is initially a constant, then a slowly varying function of time, and finally a constant again. The method consists of making a canonical transformation from the conjugate position and momentum to a pair of variables which reduce to the action-angle variables when the external parameter does not vary. The canonical equations

governing the new variables are solved by a method of iteration, and the solution is used to determine the change in the action integral when the external parameter varies at a finite rate. The adiabatic invariance of the action integral is proved to the approximation in which the canonical equations are solved. The case of a harmonic oscillator whose frequency is changing is discussed.

6795 ADIABATIC INVARIANTS IN QUANTUM MECHANICS.  
L.M.Garrido.  
Physica (Netherlands), Vol. 26, No. 7, 501-4 (July, 1960).  
It is shown that the constants of motion of a system evolving under a time-independent Hamiltonian  $H_0$  are adiabatic invariants to the  $n$ -th order in certain cases, and to all order in other cases of the system evolving under a slow time-dependent Hamiltonian  $H = H_0 + H_1(t)$ .

6796 ON THE USE OF FORMAL OPERATOR TECHNIQUES IN QUANTUM STATISTICAL MECHANICS. A.S.Reine.  
Physica (Netherlands), Vol. 26, No. 9, 700-16 (Sept., 1960).  
An alternative derivation of the linked cluster expansions for the partition function of a grand canonical ensemble is given. It is shown that the cluster coefficients in that expansion are related to connected Bloch diagrams. In a time-independent approach the contributions of those diagrams may be expressed in terms of the generalized scattering matrix of Watson. This  $t$  matrix for a hard core interaction is applied in a calculation of the first three cluster coefficients of a boson gas of impenetrable spheres. The results accord with those obtained by the binary collision method. The relation and differences in the various approaches are discussed.

6797 CLASSICAL CLUSTER INTEGRAL THEORY OF FLUIDS IN EXTERNAL FIELDS. R.V.Hanks.  
Phys. of Fluids (USA), Vol. 4, No. 5, 580-6 (May, 1961).  
Cluster integral expansions of the classical grand ensemble partition function, and singlet and pair distribution functions of fluids in external fields are discussed. Certain topological properties of terms occurring in the pair distribution function are examined and used to derive an exact integral equation for a subset of these terms. Approximations which form the activity-dependent analogues of the "chain" and "series-parallel" approximations are obtained from this equation and discussed. The thermodynamic properties of a classical single-component electron gas in a homogeneous electric field are also calculated.

6798 OPERATOR FORMALISM IN STATISTICAL MECHANICS.  
HANICS. E.Lieb.  
J. math. Phys. (USA), Vol. 2, No. 3, 341-3 (May-June, 1961).  
Considers configuration partition function,  $Z_N$ , of a classical imperfect gas of particles having rigid cores. The rigid cores result in a geometric simplification which makes it possible to find a finite recursion relation between  $Z_N$  and  $Z_{N-1}$ . From this, it is possible to express  $Z_N$  in terms of the vacuum expectation value of a finite boson operator raised to the  $N$ -th power,  $N$  being the number of particles.

6799 NOTE ON THE DERIVATION OF THE BOLTZMANN EQUATION FROM THE LIOUVILLE EQUATION.  
E.G.D.Cohen and T.H.Berlin.  
Physica (Netherlands), Vol. 26, No. 9, 717-29 (Sept., 1960).  
In Bogolubov's derivation of the Boltzmann equation from the Liouville equation a boundary condition in the past plays an essential role. It is shown that if the same boundary condition is used in the future an equation is obtained that differs from the Boltzmann equation in the sign of the collision term. Similarly, as has been noted before, if in Kirkwood's derivation of the Boltzmann equation from the Liouville equation distribution functions are used that are time-smoothed over an interval  $-\tau$  to 0 instead of from 0 to  $\tau$ , again an equation with the wrong sign for the collision term is obtained. A discussion and a possible interpretation are presented.

6800 THE THEORY OF NEUTRAL AND IONIZED GASES. THE PROBLEM OF  $n$  BODIES AT NON-ZERO TEMPERATURE. [La théorie des gaz neutres et ionisés. Le problème des  $n$  corps à température non nulle].  
Edited by C.De Witt and J.F.Detoeuf.  
Paris: Hermann; New York: John Wiley (1960) 469 pp. In English and French.

This book contains contributions from seven authors, as follows: Topics of statistical mechanics of interacting particles. Lectures on statistical mechanics of non-equilibrium phenomena. Microscopic theory of ionized gases. Hydromagnetics and the theory of

plasma in a strong magnetic field, and the energy principles for equilibrium and for stability. Asymptotic theory of systems of ordinary differential equations with all solutions nearly periodic. Landau damping. Plasma transport theory. Study of electromagnetic waves in plasmas, starting from the Boltzmann equation. Plasmas in astrophysics. Abstracts of the individual papers will appear in this or succeeding issues of "Physics Abstracts".

- 6801 HIGHER RANDOM-PHASE APPROXIMATIONS IN THE MANY-BODY PROBLEM. H. Suhl and N.R. Werthamer. Phys. Rev. (USA), Vol. 122, No. 2, 359-66 (April 15, 1961).

The usual random-phase approximation combined with an equations-of-motion technique for the many-electron problem is extended, yielding many of the known results of series summation methods in a straightforward manner. The method should apply to other types of many-body problems as well.

- 6802 EXACT TREATMENT OF PARTICLE CORRELATION FUNCTIONS AND FREE ENERGY. E. Meeron. Physica (Netherlands), Vol. 26, No. 6, 445-8 (June, 1960).

The exact integral equation for the pair distribution functions, (van Leeuwen, Groeneveld and de Boer, Abstr. 14647 of 1960) is readily derived by previously published methods (Abstr. 12372 of 1960). The relation of the new equation to the Ornstein-Zernike formula for the direct correlation function is discussed, and the importance of this relation for treatment of phase transitions is noted. Exact formulae for the Helmholtz free energy are presented. The convolution approximation, obtained by neglecting prototype graphs, and its relation to the Kirkwood superposition approximation and to the nodal expansion sequence are discussed.

- THEORY OF THE DE HAAS-VAN ALPHEN EFFECT FOR A SYSTEM OF INTERACTING FERMIONS. See Abstr. 6256

- 6803 USE OF STANDARD ANALOGUE TECHNIQUES IN SOLVING PROPAGATION PROBLEMS.

A. Gadola, V. Gervasio and C. Zaffiro.

Energia nucleare (Italy), Vol. 7, No. 10, 717-23 (Oct., 1960).

A partial differential equation describing transport phenomena is examined. A modal analysis leads to a system of ordinary differential equations which can be solved on a general purpose analogue computer. A circuit arrangement enabling a simulation of pulse transmission at a variable speed along a channel is presented.

- 6804 THEORIES OF TRANSPORT IN FLUIDS. H.S. Green.

J. math. Phys. (USA), Vol. 2, No. 3, 344-8 (May-June, 1961).

The object of this paper is to establish the equivalence of the Kubo-type transport coefficients with those obtained by the method of Chapman and Enskog. Kubo-type coefficients are derived by a simple method, based on classical mechanics, and these are found to be in general agreement with those found by Mori, who has, however, discarded some important relaxation terms. The neglect of these terms by Kubo and other authors has the effect of leaving their coefficients of diffusion and electrical conductivity divergent. It is shown quite generally that the computation of the corrected Kubo-type coefficients for dilute gases leads to the same results, and even the same calculations, as the method of Chapman and Enskog. The equivalence of the two methods for dense systems is also briefly discussed.

- 6805 EXTENSION OF THE METHOD OF NYQUIST TO NON-LINEAR LOOPS. A. Blaquièrre.

Cahiers de Phys. (France), Vol. 14, 3013-30 (Aug., 1960). In French.

The use of the Nyquist plot, which is commonly used to investigate the stability of linear systems, is extended to cover non-linear loops. A function is introduced dependent on some parameter of the state of the system, such as the amplitude of an oscillator, or the power of a nuclear reactor. The Nyquist plot is then replaced by a network of curves in the complex plane defined by values of this parameter and the frequency of the system. The geometric properties of this net completely determine the behaviour of the system considered. H. Morrison

## GENERAL MECHANICS

OPTICO-MECHANICAL ANALOGY. See Abstr. 6944

- 6806 AN INTRODUCTION TO MECHANICS, MATTER AND WAVES. U. Ingard and W.L. Kraushaar.

Reading (Massachusetts), London: Addison-Wesley Publishing Co. (1960) xv + 672 pp.

A text-book of pass degree standard which aims at a combined approach of experiment and inductive reasoning. The emphasis is on the basic concept that "mechanics is motion". The first half deals with the normal topics associated with a mechanics course. A chapter on temperature and heat is used as the transition to the internal motions of matter and chapters follow on atomic structure, kinetic theory, thermodynamics, properties of matter and mechanics of fluids. The last three chapters are devoted to waves and wave motion. There are worked examples throughout the text and problems and answers are provided. Appendices provide a range of physical data applicable to the text.

- 6807 EQUIPARTITION OF ENERGY FOR NONLINEAR SYSTEMS. J. Ford.

J. math. Phys. (New York), Vol. 2, No. 3, 387-93 (May-June, 1961).

A system of harmonic oscillators weakly coupled by non-linear forces will not achieve equipartition of energy as long as the uncoupled frequencies  $\omega_k$  are linearly independent on the integers, i.e. as long as there is no collection of integers  $\{n_k\}$  for which  $\sum n_k \omega_k = 0$  other than all  $n_k = 0$ . This result is shown to follow from the general form of the Kryloff and Bogoliuboff series solution to the equations of motion. Physically, the linear independence of the uncoupled frequencies means that none of the interacting oscillators drives another at its resonant frequency, and this lack of internal resonance precludes appreciable energy sharing in the limit as the coupling tends to zero. It is shown that the lack of equipartition of energy observed by Ulam, Fermi, and Pasta (1955) for certain nonlinear systems may be explained in terms of the preceding remarks. Moreover, a Kryloff and Bogoliuboff series solution to the appropriate equations of motion is shown to yield qualitative agreement with the Ulam, Fermi, and Pasta computer solution. Finally, a particular system of linear differential equations is solved which illustrates a mechanism whereby oscillator systems may achieve equipartition of energy.

- 6808 THE DETERMINATION OF STRESS CONCENTRATIONS WITH AN ELECTROLYTIC TANK MODEL.

T.W.G. Calvert.

Brit. J. appl. Phys., Vol. 12, No. 4, 184-8 (April, 1961).

In a loaded lamina of complicated shape stress concentrations arise which it is difficult to calculate. A model in the form of an electrolytic tank may be used to find the resultant stress at any point in a loaded lamina. The tank is made of an insulating material in the same shape as the lamina and filled with an electrolyte. It is fitted with electrodes to represent the areas over which the load is applied. The loads are represented in magnitude by the alternating currents flowing through the electrodes and in direction by the relative phase angles of the currents. The electric current at any point in the model tank can be sampled with a probe consisting of two fine wires a short distance apart. The resultant stress at a point in the loaded lamina is proportional to the electric current at the corresponding point in the model tank. This approach offers a valuable addition to means already available for finding stress concentrations in laminae of complicated shape.

- 6809 NOTE ON TWISTING OF AN ISOTROPIC CIRCULAR CYLINDER EMBEDDED IN A RESISTING MEDIUM ACTED UPON BY COUPLE AT ONE END, THE OTHER END BEING FIXED. A.K. Das.

Indian J. theor. Phys. Vol. 7, No. 3-4, 61-3 (Sept.-Dec., 1959).

- 6810 NONLINEAR ELASTICITY THEORY WITH LINEAR TRANSFORMATIONS.

H. Pfeleiderer, A. Seeger and E. Kröner.

Z. Naturforsch. (Germany), Vol. 15a, No. 9, 758-72 (Sept., 1960). In German.

The general form of the stress function method for the solution of the residual stress condition is developed using Riemann-Cartan displacement geometry. Numerical calculations of the plane residual stress condition in an isotropic medium within the range of second-order elastic theory are made and simple relationships are

given for the continuous distribution of straight parallel screw or stepped displacements. Approximate solutions for the case of a hollow circular cylinder with stress-free boundaries are derived as well as the well-known Zener formula. H.J.H.Starks

6811 DISCONTINUOUS SOLUTIONS OF SPACE PROBLEMS IN THE THEORY OF IDEAL PLASTICITY. D.D.Ivlev. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 480-6 (1958). In Russian.

Discontinuous fields of plastic stress are discussed from the purely static point of view under the assumption that, at each point of the field, two of the principal shearing stresses have the critical value. It is not investigated to what extent these discontinuous stress fields are compatible with fields of plastic flow.

Mathematical Reviews

6812 THE EXISTENCE OF OSCILLATORY MOTIONS IN THE THREE-BODY PROBLEM. K.Sitnikov. Dokl. Akad. Nauk SSSR, Vol. 133, No. 2, 303-6 (July 11, 1960). In Russian.

For abstract, see Abstr. 16659 of 1960. [English translation in: Soviet Physics-Doklady (USA), Vol. 5, No. 4, 647-50 (Jan.-Feb., 1961)].

6813 SOLUTION OF EQUATIONS OF MOTION ON AN ANALOGUE COMPUTER. J.Holan. Elektrotech.Obzor (Czechoslovakia), Vol. 49, No. 12, 644-7 (1960). In Czech.

Discusses the investigation of a rectilinear motion by calculation and with the help of an analogue computer, when the acceleration is known as function of path. Gives the circuit block diagram of the analogue computer, when time as function of path is obtained. The method is illustrated by a calculated example. N.Klein

## MECHANICAL MEASUREMENTS

6814 AN INEXPENSIVE NULL READING TORSION BALANCE. D.L.Kraus, A.W.Petrocelli and J.C.Price. Analyt. Chem. (USA), Vol. 33, No. 3, 479-80 (March, 1961).

A simple robust balance for in situ vacuum weighings in the milligram to gram range is described. The calibration curve is claimed to be linear in the range from 1 to 500 mg, and the sensitivity of the balance is 0.2 mg. R.Schnurmann

ON THE DETERMINATION OF THE COEFFICIENT OF TORSION OF THE EÖTVÖS BALANCE. NEW PROCEDURE. See Abstr. 6583

6815 CAPACITOR TECHNIQUE FOR MEASURING THE VELOCITY OF A PLANE CONDUCTING SURFACE. M.H.Rice. Rev. sci. Instrum. (USA), Vol. 32, No. 4, 449-51 (April, 1961).

The method described has the advantage that the signal voltage developed is essentially proportional to the velocity of the surface instead of to the displacement. Consequently, the method is useful in measuring a surface velocity which persists only over a small displacement interval.

VELOCITY MEASUREMENTS OF WATER IN A CLOSED LOOP WITH A COBALT-60 RADIATION CAPSULE. See Abstr. 6843

6816 MEASUREMENT OF LOAD BY ELASTIC DEVICES. B.Swindells and J.C.Evans. Notes appl. Sci. Nat. Phys. Lab. (GB), No. 21, 20 pp. (1961).

Defines units of force employed, and discusses types of instrument, their calibration and accuracy.

6817 A PIEZOELECTRIC OSCILLATOR MANOMETER. D.J.Pacey. Vacuum (GB), Vol. 9, No. 5-6, 261-3 (Nov., 1959-Jan., 1960).

A description of a simple manometer for the measurement of pressures of gases and vapours within the range 760 torr to  $10^{-1}$  torr with a linear scale. It uses the damping effect of the gas or vapour upon the sustained vibrations of a commercially available piezoelectric quartz crystal. The damping effect is examined theoretically and the behaviour of the gauge is shown to be generally in accordance with calculation.

6818 SENSITIVE METHOD FOR MEASURING SMALL ROTATIONS OF A DISTANT OBJECT. R.J.King, S.P.Middleton and I.M.G.Thompson. J. sci. Instrum. (GB), Vol. 38, No. 5, 207-8 (May, 1961).

The application of a polarimetric system to measurements of

the relative orientation of two units separated by a large distance is described. A sensitivity of 0.1 minute of arc is easily obtainable with a separation of 2000 ft.

FREQUENCY MEASUREMENT OF STANDARD  
6819 FREQUENCY TRANSMISSIONS. S.N.Kalra. Canad. J. Phys., Vol. 39, No. 3, 477 (March, 1961).

Measurements were made throughout Dec., 1960, at Ottawa, Canada, using the NRC caesium-beam frequency resonator as reference standard (with an assumed frequency of 9 192 631 770 c/s). Frequency deviations from nominal are quoted, in parts per  $10^{10}$ , for MSF (60 kc/s), GBR (16 kc/s), and WWVB (60 kc/s).

## MECHANICS OF FLUIDS

(See also Magnetohydrodynamics)

6820 THE THEORY OF AN OSCILLATING CYLINDER VISCOMETER. IV. Ali Abdel Kerim Ibrahim. Proc. Math. Phys. Soc. UAR (Egypt), No. 23, 83-90 (June, 1959).

For previous work see Abstr. 16666, 19043 of 1960. Gives a new simple and approximate theory of the periodic state of motion of an elastic liquid in a narrow annular gap between long vertical coaxial cylinders. If the inner cylinder is suspended by a fine torsion wire while the outer undergoes forced harmonic angular oscillation about its axis, the amplitude of uniform oscillation attained by the inner cylinder is calculated. The theory is compared with experimental observations. This comparison suggests that the theory may be regarded as a satisfactory description of the facts for the range of frequencies studied.

AN EXACT GRAPHICAL METHOD FOR DETERMINING THE COEFFICIENT OF VISCOSITY OF NON-ELASTIC LIQUIDS. V. Ali Abdel-Kirim Ibrahim. Proc. Math. Phys. Soc. UAR (Egypt), No. 23, 95-8 (June, 1959).

A new and exact method for measuring the coefficient of viscosity of non-elastic liquids is given using the oscillating-cylinder viscometer.

6822 A METHOD FOR MEASURING THE DYNAMIC VISCOSITY AND DYNAMIC RIGIDITY OF VISCO-ELASTIC LIQUIDS. Ali Abdel-Kerim Ibrahim. Proc. Math. Phys. Soc. UAR (Egypt), No. 23, 91-3 (June, 1959).

The dynamic viscosity and dynamic rigidity of a viscoelastic liquid can be measured with an oscillating-cylinder viscometer by introducing into the final solution of the theory of the viscometer a dimensionless parameter defined by  $\sqrt{2}Ba = Z$ , where  $2B^2 = \omega^3 \nu \rho^2 / (N^2 + \omega^2 \nu^2 \rho^2)$ ,  $\omega = 2\pi n$ ,  $n$  is the frequency,  $\nu = \eta_D / \rho$ ,  $\rho$  is the density of the liquid,  $a$  is the radius of the inner cylinder,  $N$  is the dynamic rigidity and  $Z$  may take any positive value.

6823 A GRAPHICAL METHOD FOR DETERMINING THE COEFFICIENT OF VISCOSITY OF NEWTONIAN LIQUIDS USING AN OSCILLATING CYLINDER VISCOMETER. Ali. A.K.Ibrahim and Abdel Monem I. Kabei. Z. angew. Math. Phys., Vol. 7, No. 4, 343-4 (July 25, 1956).

6824 COAXIAL CYLINDER VISCOMETER FOR NON-NEWTONIAN FLUIDS. J.C.Harper. Rev. sci. Instrum. (USA), Vol. 32, No. 4, 425-8 (April, 1961).

The viscometer is described, and details are given of mechanical construction, torque and speed measuring systems, and operating characteristics.

THEORIES OF TRANSPORT IN FLUIDS. See Abstr. 6804.

6825 A CLASS OF SOLUTIONS OF GRAD'S KINETIC MOMENT EQUATIONS. V.S.Gaikin. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 386-9 (1958). In Russian.

In the flows considered, the velocity field is spatially linear, with time-dependent coefficients, while the moments of all orders other than 1 are only time dependent. Grad's 13-moment approximation gives the exact value of the stresses, but not generally of the higher moments.

6826 EQUILIBRIUM AND MOTION OF A SPHERE IN A VISCOPLASTIC LIQUID. U.Ts.Andres.  
Dokl. Akad. Nauk SSSR, Vol. 133, No. 4, 777-80 (Aug., 1960).  
Russian.  
For abstract, see Abstr. 19051 of 1960. [English translation in: Soviet Physics—Doklady (USA), Vol. 5, No. 4, 723-6 (Jan.-Feb., 1961)].

6827 THE STRUCTURE OF THE HYDRODYNAMICS OF A VISCOUS FLUID. D.D.Ivlev.  
Dokl. Akad. Nauk SSSR, Vol. 135, No. 2, 280-2 (Nov. 11, 1960).  
Russian.

Assuming that a fluid is homogeneous, isotropic and incompressible and that the shearing stress is proportional to the rate of shear, the conventional relation between the rate of strain and the stress is readily arrived at. The author shows that the same premises are compatible with relations of a more general kind between the rate of strain and the stress. [English translation in: Soviet Physics—Doklady (USA)]. R.Eisenschitz

6828 NONSTEADY PLANAR MOTION OF AN IDEAL INCOMPRESSIBLE LIQUID. V.I.Yudovich.  
Dokl. Akad. Nauk SSSR, Vol. 136, No. 3, 564-7 (Jan. 21, 1961).  
The existence of solutions and their uniqueness are demonstrated without imposing any restriction on the length of the time interval and without considering any relevant quantity as being "small". [English translation in: Soviet Physics—Doklady (USA)]. R.Eisenschitz

6829 ON AXIALLY SYMMETRIC SUPERPOSABLE FLOWS. II. J.N.Kapur.  
Bull. Calcutta Math.Soc. (India), Vol. 52, No. 1, 14-24 (March, 1960).  
For Pt I, see Abstr. 4992 of 1960. The most general steady axially-symmetric flows of the following types are studied: Beltrami flows in viscous fluids; self-superposable flows in viscous fluids; flows of the type  $\text{curl } \vec{q}_1 = \lambda_2 \vec{q}_2$ ,  $\text{curl } \vec{q}_2 = \lambda_1 \vec{q}_1$  (with constant values for  $\lambda_1, \lambda_2$ ) in inviscid fluids (for viscous fluids it is shown that such flows do not exist); poloidal and toroidal flows superposable on each other; flows superposable on a purely toroidal flow.

6830 TRANSFORMATION OF THE LAMINAR BOUNDARY LAYER EQUATIONS FOR VARIABLE PHYSICAL PROPERTIES WITH ARBITRARY DISTRIBUTIONS OF PRESSURE AND WALL TEMPERATURE. B.Le Fur.  
C.R. Acad. Sci. (France), Vol. 252, No. 7, 988-90 (Feb. 13, 1961).  
In French.

The author considers boundary layers in which the specific heat at constant pressure is variable, the viscosity is an arbitrary function of absolute temperature, the Prandtl number is constant, and the pressure and wall temperature are both arbitrary. The author indicates a transformation of variables which will convert the equations into those appropriate to a laminar boundary layer with constant viscosity and density, subject to the use of a generalized "reference enthalpy" concept. N.Curle

6831 THE INFLUENCE OF THERMAL EFFECTS ON THE VISCOUS RESISTANCE OF A STEADY UNIFORM LIQUID FLOW. S.A.Regier.  
Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 414-18 (1958).  
In Russian.

Considers a layer of viscous fluid contained between two infinite flat plates,  $y = 0$  and  $y = h$ . The second plate moves in the  $x$ -direction with uniform velocity  $U$ . The basic equations are three ordinary differential equations: (1) the defining relation between the stress, the viscosity, and the velocity; (2) the equilibrium relation; (3) the relation between the temperature, the stress, and the viscosity. The system is studied in detail for the case when the viscosity is an arbitrary function of temperature. An integral of the function is shown to be of significance in the determination of the temperature and the asymptotic properties of a related integral are determined. Mathematical Reviews

6832 AN EXACT SOLUTION OF THE ENERGY EQUATION IN A PARTICULAR CASE OF THE MOTION OF A VISCOUS INCOMPRESSIBLE FLUID. G.A.Tirskii.  
Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 555-60 (1958).  
Russian.

In the case of a plane steady flow of a viscous incompressible fluid between two non-parallel planes, the energy equation admits so of an exact solution in terms of Weierstrass elliptic functions, when the Prandtl number is equal to unity or  $n(n+1)/12$ ,  $n$  being

an integer. The velocity and temperature profiles are investigated for the case of Prandtl number equal to unity in all possible cases. Mathematical Reviews

6833 SPONTANEOUS DISCONTINUITIES IN LAMINAR FLOW OF TWO VISCOUS LIQUIDS THROUGH POROUS MATERIAL. G.Mandl and J.H.Kruizinga.  
Z. angew. Phys. (Germany), Vol. 13, No. 2, 81-90 (Feb., 1961). In German.

The flow is considered in a one-dimensional approximation. It is assumed that all pores are filled; the main problem concerns the rate at which the available volume is shared between the two immiscible liquids. Starting from the equations of hydrodynamics, a differential equation is derived by which this fraction  $S$  is determined as a function of the time  $T$  and the coordinate  $X$ :

$$(\partial S / \partial T) + [(\partial F / \partial S)(\partial S / \partial X)] = 0,$$

where  $F$  is a given function of  $S$ . This equation is readily solved by the method of characteristics which, in the present instance, are straight lines of constant  $S$  in the  $XT$ -plane. Ambiguities arise because characteristics intersect. Section of the relevant solutions is performed by way of auxiliary equations obtained by integrating part of the fundamental equations. As a result, the function  $S$  is uniquely determined but is generally discontinuous in a number of points of the  $XT$ -plane. These discontinuities are known from observation and are discussed in some detail. R.Eisenschitz

6834 IMPACT ON A GRID OF PLATES IN SYMMETRICAL CAVITATIONAL FLOW. S.I.Parkhomovskii.  
Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 565-8 (1958).  
In Russian.

The free-boundary problem is solved.

6835 TURBULENT DIFFUSION IN A STREAM WITH A [UNIFORM] TRANSVERSE VELOCITY GRADIENT. E.A.Novikov.  
Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 412-14 (1958).  
In Russian.

Considers the diffusion of an impurity from an instantaneous point source. It is found that, for stationary turbulence, the apparent diffusivity in the stream direction is greater than the true eddy diffusivity by an amount that increases as the square of the diffusion time.

6836 METHOD FOR MEASURING TIME-AVERAGE CONCENTRATION IN A TURBULENT WAKE OF ELECTROLYTE. R.E.Sparks and H.E.Hoelscher.  
Rev. sci.Instrum. (USA), Vol. 32, No. 4, 417-20 (April, 1961).

A method is described for measuring time-average concentration profiles in the fully developed turbulent wake of a circular cylinder having a porous wall and through which a solution of electrolyte is flowing. The study was carried out in the flow field of a water tunnel. The sensing element employed was an electrical conductivity probe. The method involves the use of a thermal averaging device and a sensitive recording d.c. bridge. The method is very sensitive and is capable of high precision.

6837 TRANSVERSE WAVE MOTION ON A THIN CAPILLARY JET OF A VISCOELASTIC LIQUID. S.L.Goren and J.Gavis.  
Phys. of Fluids (USA), Vol. 4, No. 5, 575-9 (May, 1961).

The equation for transverse wave propagation on a thin capillary jet of a viscoelastic fluid in which a spatially varying tensile stress is known to exist is developed. A method of solution is developed for the special case of greatest interest,  $T_0/\rho u_1^2 \ll 1$ , where  $\rho$  is the fluid density, and  $u_1$  and  $T_0$  the average ejection velocity and tensile stress at the nozzle. Although this will allow solution for any form of  $T$  variation the solutions will not, in general, be obtainable in analytic form but may be obtained by use of an analogue computer, for example. A form in which  $T$  decays exponentially to a constant value is selected for illustration of an analytic solution, and the features of the resulting wave pattern are discussed.

6838 TEST FOR GENERAL CHARACTERISTICS OF THE FLOW THROUGH RECTANGULAR NOZZLES AT NEAR THE CRITICAL SPEEDS. M.M.Hammodat.  
Proc. Iraqi Sci. Soc., Vol. 3, 19-32 (1959).

If the one-dimensional or hydraulic analysis is made of the flow through a convergent-divergent nozzle, the velocity and, consequently, all the properties are assumed to be constant over a plane perpendicular to the nozzle or flow axis. Therefore, the critical velocity is then reached exactly at the minimum or throat section

of the nozzle. In the strict two-dimensional treatment, the assumption made above is not true. That is, the critical state occurs along a curved line in the plane of the longitudinal axis of the nozzle. An investigation was made to prove the above statement by conducting an experiment on a rectangular nozzle with the use of the water table and it was found out that the statement held true. The profile of the critical velocity took a parabolic form.

- 6839 FLOWS IN THE REGION OF THE TRANSITION SURFACE IN A LAVAL NOZZLE. O.S.Ryuzhov. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 433-43 (1958). In Russian.

Flow through an axially symmetric Laval nozzle is investigated in the neighbourhood of the intersection of the axis of symmetry with a sonic line. It is assumed that the motion is irrotational, and a transonic approximation is used. The hodograph transformation is avoided, and the analysis depends instead on a Cauchy problem with data assigned along the axis. This leads to a similarity solution of the transonic equations permitting a comparison between the plane and axially symmetric cases, which have some, but not all, features in common. Mathematical Reviews

- 6840 ON THE OSCILLATION OF A CIRCULAR CYLINDER IN A VISCOUS LIQUID CONTAINED IN A COAXIAL CIRCULAR CYLINDER. S.R.Khamrui. Bull. Calcutta Math. Soc. (India), Vol. 52, No. 1, 45-50 (March, 1960).

A discussion of the flow of a viscous liquid between two coaxial porous circular cylinders when the inner is oscillating. The solution is given in terms of Hankel functions and the results for both very small and very large frequencies is obtained. The solution for the special case of the oscillatory motion of a piston in a viscous liquid in a circular cylinder is also obtained.

T.C.Toye

- 6841 ON THE CONDITIONS OF SIMPLE WAVE FORMATION. M.Burnat. Bull. Acad. Polon.Sci. Ser. Sci. tech. (Poland), Vol. 7, No. 10, 593-7 (1959).

Generalizes the notion of Prandtl-Meyer flow, in which steady flow in two dimensions around a profile is described by a simple wave as defined by Courant and Friedrichs. Deductions are made of conditions in which unsteady flow around a profile can be described by a simple wave. (R.Courant and K.O.Friedrichs, Supersonic Flow and Shock Waves, 1948). H.N.V.Temperley

- 6842 A NOTE ON THE MEASUREMENT OF THE FORCES EXERTED BY MOVING FLUIDS ON IMMERSSED BODIES, OSCILLATING ABOUT AN AXIS. M.Daubèze and A.Claria. C.R. Acad. Sci. (France), Vol. 252, No. 6, 846-8 (Feb. 6, 1961). In French.

- 6843 VELOCITY MEASUREMENTS OF WATER IN A CLOSED LOOP WITH A COBALT-60 RADIATION CAPSULE. C.E.Moeller, C.W.Stanley and W.E.Snyder. Rev. sci. Instrum. (USA), Vol. 32, No. 2, 207-9 (Feb., 1961).

The authors give particulars of a method which should be of general value for velocity of flow measurements. Difficulties and methods of overcoming them are described. An accuracy of  $\pm 10\%$  in the velocity is claimed. E.G.Knowles

- 6844 INDUCTION FLOWMETER. P.B.Krishnaswamy. Rev. sci. Instrum. (USA), Vol. 32, No. 2, 224 (Feb., 1961).

This note discusses discrepancies between theory and experimental results appearing in a paper by Cushing (see Abstr. 1138 of 1959). [The remarks made are somewhat questionable, since no justification is given for the suggested amendments to the theory. Further, they appear now to be irrelevant, in view of the erratum issued by the author (see following abstract)]. N.Curle

- 6845 ERRATUM. INDUCTION FLOWMETER. V.Cushing. Rev. sci. Instrum. (USA), Vol. 32, No. 2, 225 (Feb., 1961).

This paper corrects a numerical slip introduced in an earlier paper (Abstr. 1138 of 1959) in solving a partial differential equation. N.Curle

- 6846 CORRECTION TO THE EMPIRICAL FORMULA FOR THE INFLUENCE OF TEMPERATURE ON SURFACE TENSION. M.Borneas. C.R. Acad. Sci. (France), Vol. 252, No. 8, 1119-20 (Feb. 20, 1961). In French.

The formula of Eötvös-Ramsay-Shields and its modifications by Katayama and Guggenheim do not apply to liquids in rotation, and the necessary corrections have now been found by the method of Lecomte du Nouy for the cases of glycol and cyclohexanol. The data obtained clearly indicate that rotation frequency directly affects changes of surface tension, and that the peripheral diameter is without influence. H.H.Hodgson

- 6847 THE MEASUREMENT OF THE SURFACE TENSION OF PURE LIQUIDS AND SOLUTIONS. J.F.Padday and D.R.Russell. J. colloid Sci. (USA), Vol. 15, No. 6, 503-11 (Dec., 1960).

The surface tensions of some pure liquids and solutions of surface-active agents were measured by methods either involving or not involving rupture of the liquid-air surface. It is shown that rupture of the surface can produce serious errors in measurement with solutions, especially when the surface tension is slow in reaching a steady value. The Wilhelmy plate method does not suffer from these errors because the plate is never pulled from the surface.

- 6848 TRANSIENT TWO-PHASE CAPILLARY FLOW IN POROUS MEDIA. D.E.Elrick. Phys. of Fluids (USA), Vol. 4, No. 5, 572-5 (May, 1961).

The dynamics of two-phase capillary displacement in a finite one-dimensional system following a step change in pressure of one phase at one end is considered. Darcy's law and the equation of continuity for each phase together with the capillary pressure-saturation relation are the fundamental equations describing the flow system. The resulting system of differential equations is linearized by assuming a linear relationship between the capillary pressure and the saturation as well as constant conductivity values of both phases (these assumptions are valid for small step changes in pressure). Solutions of the linearized problem are found and presented in some detail. In the limiting case as the conductivity of one phase becomes much greater than the other, the solution reduces to the (known) single-phase solution.

- 6849 THE GROWTH OF DROPLETS: PROGRESS REPORT No. II (FINAL). P.J.Hutton. Rep. Brit. Elect. Res. Assoc., Rep. Z/T126, 16 pp. (1960).

For earlier work see Rep. Brit. Elect. Res. Assoc., Rep. Z/T111. The variation of the mobility of ions, with the time for which they had been in highly supersaturated vapour, was observed. A low-pressure glow discharge was used to produce positive ions which were drawn into a chamber in which, under the influence of an electric field, they traversed a vapour jet of known properties produced by the expansion of saturated vapour through a nozzle. The time taken by the ions to traverse the jet was found from a measurement of the distance over which they were swept downstream. From the crossing time, the width of the jet and the pressure of the vapour in it, the mobility of the ions was obtained and hence their size was estimated. In water vapour at pressures of a few millimetres of mercury, more than ten times supersaturated, positive ions were found not to exceed a radius of some 12 Å in exposures of up to 160  $\mu$ sec. Theories of the early stages of condensation of vapours due to ions include critical stages at radii which, in water vapour, are less than 12 Å. Thus these experiments do not enable a choice to be made between those in which the ion collects vapour molecules singly, by a process akin to clustering, and those in which the ion attaches itself to an aggregate of vapour molecules, already existing. However, they do show that if the growth of the ion is by the acquisition of single vapour molecules, it can have retained only a few per cent of these with which it was in collision, under the conditions of the experiments.

- 6850 WEISSENBERG EFFECT IN THE THICK WHITE OF THE HEN'S EGG. H.G.Muller. Nature (GB), Vol. 189, 213-4 (Jan. 21, 1961).

The Weissenberg effect (Abstr. 2169 of 1949) was observed in the thick white of a hen's egg.

# LIQUID STATE

(Liquid helium is included under  
Low-Temperature Physics)

- 6851 **DISLOCATION MODEL OF LIQUID STRUCTURE.**  
S. Mizushima.  
J. Phys. Soc. Japan, Vol. 15, No. 1, 70-7 (Jan., 1960).  
Liquid structure can be considered as a lattice distorted heavily by many dislocation lines. The dislocation density is supposed to be limited by the mutual contact of the cores of the dislocation lines. Calculation of the free energy as a function of the dislocation density showed that, above a certain temperature, a lattice which has no dislocations at low temperatures changes abruptly into a liquid by the appearance of the maximum density of dislocations. The calculated heats of fusion of various metals agree fairly well with experiment if the core radius is taken to be of the order of the lattice constant. In this model the thermal expansion of liquids can be explained just in the same way as that of solids. A calculation of the Grüneisen constant of molecular liquids supported this model.
- 6852 **DERIVATION OF THE TAIT EQUATION AND ITS RELATION TO THE STRUCTURE OF LIQUIDS.**  
R. Ginell.  
J. Chem. Phys. (USA), Vol. 34, No. 4, 1249-52 (April, 1961).  
The Tait equation,  $-(dV/dP) = J/(L + P)$  is theoretically derived from association theory. It is shown that the constant  $L$ , which is temperature dependent should also have a small pressure dependence. From the equation for the constants it is shown how the volume of holes in the liquid can be calculated. The number average degree of association of a liquid is defined and an equation for its determination is given. The general structure of liquids in light of this equation is discussed.
- 6853 **DYNAMICS OF ATOMIC MOTIONS IN LIQUIDS AND COLD NEUTRON SCATTERING.**  
A. Rahman, K.S. Singwi and A. Sjölander.  
Phys. Rev. (USA), Vol. 122, No. 1, 9-12 (April 1, 1961).  
The self-correlation function for the motion of an atom in a liquid is constructed in a manner which simulates the behaviour of this function between the two extreme cases, viz., that in a solid and that in a simple diffusive model. Using this function, the differential scattering cross-section for cold neutrons is calculated for liquid lead and compared with available experimental results. It appears that even in a simple liquid like lead the solid-like behaviour of atomic motions persists for a considerable time.
- 6854 **CLUSTERING IN THE CRITICAL REGION.**  
G.W. Brady and J.I. Petz.  
J. Chem. Phys. (USA), Vol. 34, No. 1, 332-3 (Jan., 1961).  
A preliminary note showing semi-quantitative results of temperature variation of small angle X-ray scattering from a two-component liquid system. The length of the critical region indicates a surprising degree of clustering. V.R. Switsur
- 6855 **AN EXTENDED HOLE THEORY OF LIQUIDS.**  
G.E. Blomgren.  
J. Chem. Phys. (USA), Vol. 34, No. 4, 1307-15 (April, 1961).  
The hole theory of liquids is extended to include the effect of all configurations of particles and holes on the partition function. The potential energy of a particle in a cell surrounded by a given number of particles and holes is approximated by a Lennard-Jones and Devonshire-type function appropriate to the given number of neighbours. The partition function is derived on the basis of the model and an expansion procedure is used to simplify the problem of the summation over all configurations of particles and holes. The equation of state is obtained from the partition function and expressed in terms of a reduced volume and temperature, a cell size parameter and known physical constants. Possible extensions of the theory are discussed.
- 6856 **CONCENTRATION DEPENDENCE OF POLYMER CHAIN CONFIGURATIONS IN SOLUTION.** H. Yamakawa.  
J. Chem. Phys. (USA), Vol. 34, No. 4, 1360-72 (April, 1961).  
On the basis of the theory of fluids and the statistical thermodynamics of dilute chain polymer solutions, the segment distribution functions are formally derived as a power series in concentra-

tion. The mean-square radius of gyration and end-to-end distance at finite concentrations are calculated by using the general equations derived and introducing the modified random flight model. Evaluation is carried out up to the linear term in concentration. The coefficients of the linear terms are obtained as a power series in the excluded volume parameter, and also appropriate closed forms for these are proposed, which might be properly applied to good solvent systems. The results show that the polymer chain dimension decreases with increasing concentration. Then the concentration-dependent term in the intramolecular intensity function in light scattering is evaluated. It is pointed out that the separation of this term and the intermolecular correlation leads to the possibility of estimation of the polymer chain dimension at finite concentrations by light-scattering measurements. Finally, the Huggins constant  $k'$  in the viscosity-concentration relation is phenomenologically calculated. The concentration dependence of polymer chain dimensions satisfactorily explains the effect of solvent power on the constant  $k'$ .

- 6857 **INVESTIGATION OF MOLAR SOUND VELOCITY [R] IN MELTS AND SOLUTIONS.**  
P.R.K.L. Padmini and B. Ramachandra Rao.  
Z. Phys. (Germany), Vol. 162, No. 3, 245-53 (1961). In German.  
Ultrasonic velocity studies were carried out in organic solutions of six low melting point organic solids and the melts of these solids. The constancy of  $R$  is established over a wide range of temperature in the melt state. It is found that  $R$  is strictly linear with concentration expressed in mole fraction of the solute and the average extrapolated value for 100% concentration of the solute is compared with that from the melt state and also with the theoretical computed values due to Rao's atomic increment method and Lagemann's bond increment method.
- 6858 **ULTRASONIC PROPAGATION THROUGH AQUEOUS SOLUTIONS OF ACETATES.**  
M. Krishnamurthi and M. Suryanarayana.  
J. Phys. Soc. Japan, Vol. 15, No. 2, 345-8 (Feb., 1960).  
Using the pulse method in the range of 2 to 26 Mc/s the ultrasonic absorption, velocity and the adiabatic compressibility were studied in eleven aqueous acetate solutions up to a concentration of 1 mole/litre. The substances studied were the acetates of lithium, sodium, potassium, ammonium, magnesium, calcium, strontium, barium, zinc, cadmium and lead. Absorption in mercuric acetate was studied only at 2 and 6 Mc/s. Two regions of relaxation were noticed, one below 10 Mc/s and the other between 10 and 26 Mc/s. The first relaxation is ascribed to the dissociation reaction of the salt and the second one to the monomer-dimer reaction of the acetic acid formed by the hydrolysis of the salt in water.
- 6859 **ULTRASONIC PROPAGATION THROUGH BINARY MIXTURES CONTAINING ACETIC ACID.**  
M. Krishnamurthi and M. Suryanarayana.  
J. Phys. Soc. Japan, Vol. 15, No. 2, 349-52 (Feb., 1960).  
Ultrasonic absorption was studied by the pulse technique in binary mixtures of acetic acid in water, methyl and ethyl alcohols, and covering the range 2-26 Mc/s. The mixtures were studied from 0 to 100% by weight of the acid. In all the three mixtures, two relaxation processes are observed, the first occurring below the frequency range of the study. The second one occurs near 20 Mc/s in the acid-water mixtures and at much higher frequencies in the other cases. It is qualitatively explained that the monomer-dimer reaction of the acetic acid giving a relaxation near 1 Mc/s shifted to a higher frequency when mixed in a solvent thus giving rise to a second relaxation in the mixtures.
- MOLECULAR THEORY OF LIGHT SCATTERING IN GASES AND LIQUIDS.** See Abstr. 6965
- 6860 **INFRARED SPECTRA OF WATER.**  
R. Mecke.  
Current Sci. (India), Vol. 30, No. 2, 43-4 (Feb., 1961).  
Dilution of  $H_2O$ ,  $D_2O$  and  $HDO$  in  $SbCl_3$  eliminates effects of hydrogen bonding. Vibration bands are sharp and the stretching vibrations of  $HDO$  coincide with those of  $H_2O$  and  $D_2O$ , indicating that "there is no great interaction between the vibrations of the  $HO$  and  $DO$  valence bonds". Splitting of the bending vibration at  $1600\text{ cm}^{-1}$  suggests  $O$ -bonding to  $Sb$ . G.F. Lothian

**6861  $n \rightarrow \pi^*$  ELECTRONIC TRANSITION IN PURE ALKALI NITRATE MELTS.** G.P. Smith and C.R. Boston.  
J. chem. Phys. (USA), Vol. 34, No. 4, 1396-1406 (April, 1961).  
The lowest-energy transition ( $n \rightarrow \pi^*$ ) of the nitrate ion was found to shift in energy and intensity in a systematic way over the series of molten alkali nitrates from  $\text{LiNO}_3$  through  $\text{CsNO}_3$ . The energy  $E$  of the band maximum varied in a linear way with the cationic radius. At  $365^\circ\text{C}$  (extrapolated for  $\text{CsNO}_3$ )  $E$  in electron volts was given by  $(3.81 + 0.33/r_0)$ , where  $r_0$  is the cationic radius (Ahrens) in Å. The temperature dependence  $dE/dT$  was of the order of  $-10^{-4}$  eV/deg and increased in magnitude with increasing cationic  $1/r_0$ . The  $f$  number (oscillator strength) decreased steadily along the series of alkali nitrates from  $4.1 \times 10^{-4}$  for  $\text{LiNO}_3$  down to  $0.86 \times 10^{-4}$  for  $\text{RbNO}_3$  and then rose again to  $1.0 \times 10^{-4}$  for  $\text{CsNO}_3$ . The thermal coefficient  $(1/f)(df/dT)$  was in the range of  $10^{-4}$  to  $10^{-3}$  deg $^{-1}$ . The bandwidth changed by only a small amount for changes either in cation or in temperature. The origin of the observed shifts was considered in terms of interionic cohesive forces by application of the Franck-Condon and conservation of energy principles to a localized transition in a classical ionic melt. Digital computer procedures for profile analysis are described whereby an absorption band may be separated from an overlapping absorption edge.

**EFFECT OF SOLVENT AND SOLUTE STRUCTURE ON SCINTILLATOR PULSE HEIGHTS.** See Abstr. 6236

**6862 VISCOSITY AND TEMPERATURE EFFECTS IN FLUORESCENCE.** E.J. Bowen.  
Disc. Faraday Soc. (GB), No. 27, 40-2 (1959).  
"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 4920 of 1961). Fluorescence measurements have been the means of examining the nature of the transfer of electronic energy from one molecule to another and from one part of a molecule to another part. In this paper the possibility is explored of using fluorescence measurements to investigate the change over from one electronic state of a molecule to another.

**6863 YIELD OF FLUORESCENCE AND SPECTRA OF CHLOROPHYLL IN VISCOUS MEDIA.**  
D. Frackowiak and T. Marszałek.  
Bull. Acad. Polon. Sci. Ser. Sci. math. astron. phys. (Poland), Vol. 8, No. 10, 713-17 (1960).  
It is suggested that as aggregates of chlorophyll molecules are formed, the emission and absorption of the solution diminishes, indicating that the degree of aggregation of chlorophyll is greater in collodium than in ether. There is a 50 Å shift in the maxima of the emission and absorption curves in collodium relative to those for ether. This is of the order to be expected with different solvents.  
I. Cooke

**6864 LIGHT AND HIGH ENERGY INDUCED ENERGY TRANSFER IN LIQUID AND RIGID ORGANIC SCINTILLATORS.** F.H. Brown, M. Furst and H. Kallmann.  
Disc. Faraday Soc. (GB), No. 27, 43-56 (1959).  
"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 4920 of 1961). In contrast to excitation by high energy where the primary energy is absorbed mainly in the bulk material, under light excitation in the component which absorbs the incoming radiation may be varied in many solutions by using appropriate wavelengths. Thus the solute and solvent may each be separately excited. By comparing fluorescence under both conditions an absolute measurement of such determinations show that the probability of solute can be made. The results of such determinations show that the probability of energy transfer from effective solvents approaches unity if the solute concentration is sufficient. This occurs particularly when the lowest excitation level of the solvent is energized, but there are indications that the quantum efficiency is near unity when higher levels are excited. Three modes of energy transfer are discussed. Experiments using rigid media aid in discriminating among these, since material diffusion transfer does not occur. Definite differences are found in rigid and non-rigid media. Quenching materials are found to be less effective in rigid media. The use of an intermediate "solvent" produces fluorescence enhancement in rigid as well as non-rigid media. Polymethylmethacrylate and polystyrene show somewhat different energy-transfer properties. It appears that migration transfer plays an important role, at least in rigid media.

**6865 ENERGY TRANSFER IN FLUORESCENT PLASTIC SOLUTIONS.** J.B. Birks and K.N. Kuchela.  
Disc. Faraday Soc. (GB), No. 27, 57-63 (1959).  
"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 4920 of 1961). Solvent-solute energy transfer in tetraphenyl-1:3-butadiene + polystyrene solutions was studied by observing the fluorescence excitation spectra at 220-350 m $\mu$ . At low concentrations the transfer is purely radiative, but at  $>10^{-4}$  M non-radiative transfer occurs. The transfer is independent of excitation wavelength at 270-240 m $\mu$ , but decreases at shorter wavelengths, probably due to the reduced excitation depth. There is some evidence for a change in the polystyrene emission spectrum when excited by 220 m $\mu$  radiation. The results are compared with data on similar solutions excited by ionizing radiations.

**6866 DECAY OF PHOSPHORESCENCE OF TRYPAFLAVINE IN GELATINE.** M. Frackowiak and H. Waleryś.  
Acta phys. Polon. (Poland), Vol. 19, No. 2, 199-215 (1960).  
The absorption spectra and decay curves of phosphorescence of trypaflavine in gelatine were investigated as a function of the pH value of the aqueous trypaflavine solution in which the gelatine is coloured. It appeared that they vary with pH of the above solution. The observed decay curves and their decomposition into simple exponential functions can be explained by assuming the trypaflavine molecule to exhibit one metastable level only and by taking into account the observed pre-excitation effects.

**6867 ENERGY TRANSFER AND QUENCHING PROCESSES IN THE SYSTEM CYCLOHEXANE-BENZENE-TERPHE-NYL-OXYGEN.** A. Weinreb.  
J. chem. Phys. (USA), Vol. 34, No. 4, 1316-19 (April, 1961).  
A quantitative explanation of the results of Berry and Burton (Abstr. 1100 of 1956) is offered. Some additional results on the effect of oxygen on the fluorescence of terphenyl are included.

**6868 THE DIELECTRIC PROPERTIES OF WATER.** J.B. Hasted.  
Progress in dielectrics. Vol. 3 (see Abstr. 5414 of 1961) p. 103-4.  
Reviews the experimental data and theories of the dielectric properties of ice, water, aqueous solutions, colloids and bound water over the last decade. It includes a 4-page diagrammatic summary of the available microwave techniques for dielectric measurements on liquids and solids. 159 refs.  
J.B. Birks

**6869 STUDY OF ELECTRIC BREAKDOWN OF LIQUID DIELECTRICS USING SCHLIEREN OPTICAL TECHNIQUES.** B. Farazmand.  
Brit. J. appl. Phys., Vol. 12, No. 5, 251-4 (May, 1961).  
The work is a contribution to the understanding of the mechanism of electric breakdown in liquid dielectrics. The liquid dielectric chosen throughout the experiments was  $n$ -hexane, because an extensive literature exists on the breakdown of this material. The applied voltage was a rectangular pulse of different durations supplied from a 125 kV, five-stage Marx-Goodlet impulse generator. A novel rotary multiple electrode containing eight pairs of electrodes was incorporated in a simple and efficient fractionation-filtration unit. A protection circuit, incorporating an inverter and a trigatron, limited the duration of breakdown current. A series of photographs of the state of  $n$ -hexane under the applied electric field was taken by the schlieren technique, using a spark light-source and a still camera. A statistical survey of the results shows the formation of a region of very low refractive index at the cathode. It is suggested that this is due to streamers with a very large number of branches, which propagate towards the earthed electrode. The rate of growth increases with voltage and above a certain voltage, if enough time is allowed, the stepped streamers bridge the electrode gap and breakdown of the liquid results.

**6870 RELAXATION TIMES OF SOME DIPOLAR LIQUID MIXTURES AT 3 cm.** H.N. Srivastava.  
Current Sci. (India), Vol. 29, No. 8, 306-7 (Aug., 1960).  
The concentration variation method of Krishna [Trans Faraday Soc. (GB), Vol. 53, Pt 6, 767 (June, 1957)] was used to determine dielectric relaxation times of mixtures of dipolar liquids in benzene at 3 cm wavelength. Standard short-circuited line methods were used to measure the dielectric properties. Four dipolar liquids were used; acetone, ethylbutyl ketone, benzyl alcohol and benzylamine. For mixtures of equal volumes of two such liquids in benzene the relaxation time was found to be the average of the two individual relaxation times, for every pair tested.  
R.G.C. Arridge

6871 DIELECTRIC BEHAVIOUR AT THE MISCIBILITY POINT IN METHANOL-WATER-BENZENE SYSTEM. V.V.Suryanarayana and K.M.Somasundaram. *J. sci. Industr. Res. (India)*, Vol. 19B, No. 10, 375-7 (Oct., 1960). The non-mixing of two immiscible liquids of a heterogeneous system was investigated by studying the physical properties of the system at the point of disappearance of the phase boundary after the addition of an optimum amount of a third component, which is freely miscible with the two heterogeneous components. At the point of miscibility it was observed that the relation

$$\sum L_k x_k = L_{1,2,3}$$

where  $L$  represents volume polarization and  $x$  the mole fraction, holds good in some systems. The system methanol-water-benzene was found to comply with the above relationship. Some implications of this are discussed.

A REVIEW OF LIQUID SEMICONDUCTORS. See Abstr. 6137

6872 MEASUREMENT OF THE VARIATION OF THE LONGITUDINAL RELAXATION TIME ( $T_1$ ) OF PROTONS IN CHLOROFORM AS A FUNCTION OF MAGNETIC FIELD. J.Ottavi. *C.R. Acad. Sci. (France)*, Vol. 252, No. 10, 1439-41 (March 6, 1961). In French.

By making measurements in fields of the order of 1 G, it was possible to detect and measure that part of the relaxation rate arising from the scalar interaction of protons with chlorine nuclei, through the characteristic field dependence of this process. E.F.W.Seymour

6873 ELECTRONIC PARAMAGNETIC RELAXATION TIMES IN POTASSIUM-AMMONIA AND POTASSIUM-DEUTEROAMMONIA SOLUTIONS. C.A.Hutchison, Jr and D.E.O'Reilly. *J. chem. Phys. (USA)*, Vol. 34, No. 4, 1279-84 (April, 1961). The longitudinal and transverse paramagnetic relaxation times  $T_1$  and  $T_2$  for  $K-NH_3$  and  $K-ND_3$  solutions, were measured over a range of concentrations and temperatures.  $T_1$  is found to be equal to  $T_2$  at the higher concentrations. At the lower concentrations, the values of  $T_1$  are found to be greater than those of  $T_2$ , although at the very lowest concentrations studied they are again approaching each other in value with decreasing molarity. The product of the linewidth at zero r.f. field by the ratio of temperature to viscosity is found to be constant in both  $NH_3$  and  $ND_3$  over the temperature range studied.

6874 THE CONCENTRATION DEPENDENCE OF THE MAGNETIC SCREENING OF THE  $F^{19}$  NUCLEUS IN THE SYSTEMS  $KHF_2-H_2O$  AND  $KHF_2-KF-H_2O$ . Van I-tsyu [Wang I-ch'iu] and F.I.Skripov. *Dokl. Akad. Nauk SSSR*, Vol. 136, No. 1, 58-60 (Jan. 1, 1961). In Russian.

Measurements of the chemical shift of the nuclear magnetic resonance line, confirmed earlier estimates of this quantity. Predictions of its variation with concentration agree reasonably well with experiment. [English translation in: *Soviet Physics-Doklady (USA)*]. K.G.Major

## MECHANICS OF GASES

6875 A CLASS OF SELF-SIMILAR [PATTERNS OF] MOTION OF AN ULTRARELATIVISTIC GAS. V.A.Skripkin. *Dokl. Akad. Nauk SSSR*, Vol. 136, No. 4, 791-4 (Feb. 1, 1961). Relativistic equations of motion of a fluid are simplified in the limit of energy being proportional to momentum (photons). A pattern of motion of central symmetry is described by a dimensionless equation which is valid on the assumption that there is a single constant specific to the gas and that this quantity has the dimension of pressure. With this equation relations between pressure, velocity and a single coordinate are established. Solutions of this equation are obtained; they may include propagation of a shock front. Particular solutions are discussed in detail. [English translation in: *Soviet Physics-Doklady (USA)*]. R.Eisenschitz

6876 THE VISCOSITY OF SUPERHEATED STEAM UP TO 270°C. J.Kestin and H.E.Wang. *Physica (Netherlands)*, Vol. 26, No. 8, 575-84 (Aug., 1960).

Describes a series of measurements on the viscosity of superheated steam obtained with the aid of an oscillating-disk viscometer. Measurements were made along the following four approximate isotherms: 136°C, 168°C, 198°C and 234°C, from about atmospheric to saturation pressure. It is considered that the results are accurate to  $\pm 0.5\%$ . The measurements show excellent agreement with an earlier series obtained by Moszynski and the combined results were used to provide a tabulation for superheated steam up to 270°C. The extrapolated results for 1 atm show good agreement with the recent measurements due to Shifrin. The results reveal an anomaly in that the pressure coefficient of viscosity is negative, decreasing with increasing temperature down to zero at 270°C.

6877 THE INFLUENCE OF THE DENSITY ON THE VISCOSITY COEFFICIENT OF GASES. J.M.J.Coremans and J.J.M.Beenakker. *Physica (Netherlands)*, Vol. 26, No. 8, 653-63 (Aug., 1960).

A corresponding states treatment based on molecular units is given for the density dependence of the viscosity coefficient of several gases. The increase in the viscosity showed a very simple temperature dependence. An empirical relation is given that makes it possible to predict the increase of the viscosity coefficient for simple gases over a large range of densities and temperatures.

6878 VISCOSITY OF DISSOCIATED GASES FROM SHOCK-TUBE HEAT-TRANSFER MEASUREMENTS. R.A.Hartunian and P.V.Marrone. *Phys. of Fluids (USA)*, Vol. 4, No. 5, 535-43 (May, 1961).

Measurements of the heat transfer from dissociated oxygen to the sidewall of a shock-tube were made over a wide range of operating conditions using the methods of thin-film thermometry. Numerical solutions of the equilibrium shock-tube wall boundary layer equations for several values of the Lewis number have been obtained. The results show the heat transfer to be very weakly dependent upon the Lewis number. This fact indicates the shock-tube wall boundary layer to be a source for experimental determinations of the viscosity coefficient of dissociated gases. Experimental data obtained in the equilibrium boundary layer regime agree with the theory at the low temperatures, and rise above the theoretical curves at the higher temperatures. This difference between theory and experiment is attributed to the uncertainty in the calculated viscosity coefficient used in the theory. The experiments were then used to determine new values for the viscosity coefficient of high temperature, dissociated oxygen. These values are considerably higher than those predicted theoretically using a Lennard-Jones potential or Sutherland's formula.

6879 ISOTHERMS OF NEON AT TEMPERATURES BETWEEN 0°C AND 150°C AND AT DENSITIES UP TO 1100 AMAGAT (PRESSURES UP TO 2900 ATMOSPHERES). A.Michels, T.Wassenaar and P.Louwerse. *Physica (Netherlands)*, Vol. 26, No. 7, 539-43 (July, 1960).

The compressibility isotherms of neon are given at temperatures from 0°C up to 150°C and at densities up to 1100 amagat, the maximum pressure being about 2900 atmospheres.

6880 TRAVELLING WAVE EQUATIONS OF GAS DYNAMICS. Yu.Ya.Pogodin, V.A.Suchkov and N.N.Yanenko. *Priklad. Mat. i Mekh. (USSR)*, Vol. 22, No. 2, 188-96 (1958). In Russian.

The problem considered is that of finding solutions of the set of linear equations

$$a_{ijk}(u_1, \dots, u_m) \frac{\partial u_j}{\partial x_k} = 0 \quad (i, j, k = 1, \dots, m)$$

such that the functional relationship

$$\varphi(u_1, \dots, u_m) = 0$$

is satisfied. A formal solution method is given and then applied to a particular case — the two-dimensional unsteady motion of a polytropic gas. The method leads to a quasi-linear partial differential equation with one less independent variable than the original set. When the flow is isothermal, this equation becomes linear and readily soluble and a specific example is worked out for this special case. Mathematical Reviews

6881 LIMITING SELF-SIMILAR ONE-DIMENSIONAL UNSTEADY GAS FLOWS. CAUCHY'S PROBLEM AND THE PISTON PROBLEM. S.S.Grigoryan. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 301-10 (1958). In Russian.

6882 CONSTRUCTIONS OF THE EXACT SOLUTIONS OF THE EQUATIONS OF ONE-DIMENSIONAL GAS DYNAMICS IN THE PRESENCE OF DISCONTINUITIES. E.V.Ryáenov.

Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 5, 720 (1958). In Russian.  
A particular solution of the Ricatti equation is used to construct a general solution with a shock discontinuity for arbitrary values of the parameters.

6883 NONLINEAR CONICAL FLOW OF A GAS. B.M.Bulakh.

Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 6, 781-8 (1958). In Russian.

6884 A REFINEMENT OF THE LINEARIZED TRANSONIC FLOW THEORY. I.Hosokawa.

J. Phys. Soc. Japan, Vol. 15, No. 1, 149-57 (Jan., 1960).

A new method is proposed to calculate the velocity and pressure distributions around a thin symmetrical aerofoil or a slender body of revolution flying at transonic speed. It is essentially a refinement of the linearized transonic flow theory due to Oswatitsch and Maeder, such that a correction term is introduced to take account of the nonlinear nature of the transonic flow. As examples of application, a symmetrical circular-arc aerofoil and a circular-arc body of revolution in sonic flow are dealt with, and the results are found to be in good agreement with experiments, except for the rear portion in the latter case.

6885 EXPANSION PROCEDURES AND SIMILARITY LAWS FOR TRANSONIC FLOW. J.D.Cole and A.F.Messiter.

Z. angew. Math. Phys. (Germany), Vol. 8, No. 1, 1-25 (1957).

6886 AN EXAMPLE OF TRANSONIC FLOW OF A GAS WITH A SUPERSONIC ZONE TERMINATED BY A

CURVED SHOCK WHICH ENDS INSIDE THE FLOW. I.Bibosunov. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 311-19 (1958). In Russian.

HEAT TRANSFER WITH GASEOUS HYDROGEN IN TURBULENT FLOW. See Abstr. 6973

POROSITY AND SURFACE AREA OF A GRANULAR BED FROM MEASUREMENTS OF THE FLOW OF AIR THROUGH THE BED AND MEASUREMENTS OF THE GRANULAR SHAPE FACTORS. See Abstr. 6558

TWO-DIMENSIONAL FLOW OF AN IDEAL GAS WITH SMALL ELECTRIC CONDUCTIVITY PAST A THIN PROFILE. See Abstr. 7134

DISCONTINUITY PROPERTIES OF LAMINAR FLAMES. See Abstr. 6977

## Shock Waves

6887 BURGERS' EQUATION AND ITS APPLICATIONS TO THE THEORY OF SHOCK WAVES. P.Germain.

Cahiers de Phys. (France), Vol. 14, 285-99 (July, 1960). In French.

In a series of papers designed to throw light on the mechanics of turbulent motion, Burgers investigated solutions of an equation which, although simpler than the equations of fluid motion, still included the essential mathematical features. In this paper the author has used this simplified equation to illustrate how the dissipative effects of viscosity and the non-linearity of the inertia terms each cause deviations from the predictions of the linear theory of sound waves of infinitesimal amplitude. N.Curle

6888 PROPERTIES OF SHOCK WAVES PRODUCED BY CONDENSED DISCHARGES IN A LOW-PRESSURE GAS.

M.Cloupeau. J. Phys. Radium (France), Vol. 21, No. 3, 189-93 (March, 1960). In French.

The observation of luminous shock waves does not necessarily

signify thermal ionization of a gas. It is shown that two other effects may operate in the case of shock waves produced by electrical discharges at low pressures: (1) Parasitical discharge effects can cause ionization of the gas ahead of the shock front which then becomes visible, even in the case of low Mach numbers. (2) The shock front and the contact surface are sometimes very close together or, for practical purposes, indistinguishable. The emission of light observed behind the shock front may then be due chiefly to the presence of gas ionized by the electrical discharge.

THE DECAY OF AN ARBITRARY DISCONTINUITY IN A CONTINUOUS MEDIUM. See Abstr. 7057

6889 REFRACTION OF UNDERWATER EXPLOSION SHOCK WAVES BY A STRONG VELOCITY GRADIENT.

R.R.Brockhurst, J.G.Bruce, Jr and A.B.Arons. J. Acoust. Soc. Amer., Vol. 33, No. 4, 452-6 (April, 1961).

The effects of a strongly refracting summer thermocline on the initial pressure pulse from an underwater explosion were accurately measured in a flooded quarry. The familiar exponentially decaying pulse shape was observed to be drastically altered in highly divergent regions of the field. Closely spaced measurements permitted these shape changes, as well as the increased amplitude and decreased time constant in a caustic region, to be followed continuously from the source. It is presently impossible to compute the observed pulse shapes although measured shock pressures agreed well with ray-theory predictions except near the caustic. Measurement time differences between initial arrivals and both second direct arrivals and surface reflections agreed quite exactly with predictions.

6890 MAGNETICALLY INSULATED SHOCK TUBE.

R.G.Fowler and E.B.Turner. Phys. of Fluids (USA), Vol. 4, No. 5, 544-51 (May, 1961).

Experiments were carried out in a small (1 in. diameter) electrically driven shock tube with a homogeneous longitudinal magnetic field of up to 20 000 G in both the discharge and expansion chambers. A 1600 J capacitor bank was used with deuterium pressures of 150  $\mu$  Hg or more, giving shock velocities of up to 8 cm/ $\mu$ sec. At magnetic field strengths of 7500 G and higher, several effects were found. The shock velocity was substantially increased. An interface, such as seen in diaphragm-type shock tubes was clearly defined in the wave-speed photographs. The reflected shock velocities were abnormally high, indicating a  $\gamma$  of more than 5/3. The shock fronts were observed to be convex.

## GASEOUS STATE

6891 AN ELEMENTARY THEORY OF THERMAL AND PRESSURE DIFFUSION IN GASEOUS BINARY AND COMPLEX MIXTURES. I. GENERAL THEORY. M.F.Laranjeira. Physica (Netherlands), Vol. 26, No. 6, 409-16 (June, 1960).

A general treatment of the problem of thermal and pressure diffusion is given. Equations for thermal and pressure diffusion factors as well as for thermal and pressure diffusion ratios are deduced. Two kinds of free paths are considered one related to number density transfer and the other one to mean thermal speed transfer. The ratio of these two free paths depends on the hardness of the molecules.

6892 AN ELEMENTARY THEORY OF THERMAL AND PRESSURE DIFFUSION IN GASEOUS BINARY AND COMPLEX MIXTURES. II. BINARY MIXTURES WITH EXPERIMENTAL COMPARISON. M.F.Laranjeira. Physica (Netherlands), Vol. 26, No. 6, 417-30 (June, 1960).

The general treatment of thermal and pressure diffusion given in Pt I is worked out for binary mixtures, by making particular assumptions on the mean free paths,  $l_k$  and  $l_k'$ , for number density and for mean thermal speed transfer respectively. The resulting equations can be easily applied in practice and account for most characteristics of thermal diffusion. It is shown that the inverse of the thermal diffusion factor is linearly dependent on concentration to a first approximation, except for the unusual cases to which a change of sign of the thermal diffusion factor with concentration may occur. Such linear dependence has been confirmed by experiments and is also observed for Chapman's r.e.s. first approximation.

- 6893 **EXPERIMENTAL AND THEORETICAL THERMAL DIFFUSION FACTORS IN GASEOUS MIXTURES. III. TERNARY MIXTURES.** M.F.Laranjeira and J.Kistemaker. *Physica (Netherlands)*, Vol. 26, No. 6, 431-9 (June, 1960).  
Observations were carried out with He-Ar, He-Ne, H<sub>2</sub>-Ne and Ne-Ar mixtures which are regarded as multicomponent mixtures, mainly to study the variation of the thermal diffusion factors for neon and argon isotopes with the concentration of an added gas. The thermal diffusion factor of argon isotopes, Ar<sup>36</sup> and Ar<sup>40</sup>, increases with increasing concentration of helium and neon. A marked decrease was observed for the thermal diffusion factor of Ne<sup>20</sup>-Ne<sup>22</sup> with increasing concentrations of helium, hydrogen and argon. All the inverses of thermal diffusion factors which could be measured in the above multicomponent mixtures over sufficiently large concentration range, appear to be linearly dependent on concentration. The case of Ne<sup>20</sup>-Ne<sup>22</sup> with addition of Ar is unreliable. Experimental results are in qualitative agreement with the elementary theory previously developed. The variation of the isotopic thermal diffusion factor with concentration is markedly determined by the "hardness" of the added gas.
- 6894 **SELF-DIFFUSION OF <sup>4</sup>He AND QUANTUM CORRECTIONS.** S.C.Saxena. *Physica (Netherlands)*, Vol. 26, No. 9, 730-6 (Sept., 1960).  
Recent low temperature data (1.74 to 296°K) of Bendt (Abstr. 8623 of 1958) on the interdiffusion of He<sup>3</sup>-He<sup>4</sup> are interpreted. Quantum mechanical expressions are suggested for calculating the self-diffusion of a gas from the isotopic interdiffusion coefficient, and for the Schmidt number in analogy with the classical expressions. It is found that the Schmidt number is no more constant at low temperatures but varies in accordance with the proposed quantum mechanical expressions. The experimental low temperature diffusion coefficients agree well with the quantum mechanically calculated values.
- 6895 **DIFFUSION AND THERMAL DIFFUSION IN Ne-CO<sub>2</sub>.** S.Weissman, S.C.Saxena and E.A.Mason. *Phys. of Fluids (USA)*, Vol. 4, No. 5, 643-8 (May, 1961).  
Values of the thermal diffusion factor  $\alpha_T$  and the ordinary diffusion coefficient  $D$  for Ne-CO<sub>2</sub> mixtures were measured over a temperature range of about from -78° to +350°C by using the radioactive tracer C<sup>14</sup>O<sub>2</sub>. The thermal diffusion factor exhibits an unusual negative temperature dependence similar to that for A-CO<sub>2</sub> mixtures. The data for Ne-CO<sub>2</sub> are in good agreement with relations between measurable quantities, derived from the Chapman-Enskog theory, which are independent of the choice of force law. The experimental values are compared with values calculated from the theory using the Lennard-Jones (12-6) potential. The agreement is good for  $D$  but very poor for  $\alpha_T$ . A corresponding states treatment based on the general form of the relations of the Chapman-Enskog theory has been used to correlate the thermal diffusion factor of Ne-CO<sub>2</sub> with those of He-CO<sub>2</sub> and A-CO<sub>2</sub> mixtures. Therefore it appears as if the discrepancy between the theoretical values and the observed values is due primarily to the force model.
- 6896 **THE REDUCED EQUATION OF STATE, INTERNAL ENERGY AND ENTROPY OF ARGON AND XENON.** J.M.H.Levelt. *Physica (Netherlands)*, Vol. 26, No. 6, 361-77 (June, 1960).  
Tables of the equation of state, internal energy and entropy of argon and xenon, at regular intervals of density and temperature, are presented in the reduced form appropriate for fundamental theoretical work on the equation of state. The reductions were performed with the molecular parameters of the Lennard-Jones 6-12 potential. The reliability of the reduction factors is discussed. The effect of the uncertainty of these factors on the results of the reduction is investigated and found to be appreciable at liquid densities. Tables for the equation of state of argon and xenon, reduced with the critical constants as parameters, are also given, to be used in the search for general empirical equations of state. In the reduction with molecular parameters as well as in that with critical constants, deviations from corresponding states are established for argon and xenon. It is shown that these deviations exceed the uncertainties introduced by the limited accuracy of the reduction factors. Possible explanations for the observed deviations are offered.

- 6897 **VIRIAL COEFFICIENTS OF HYDROGEN AND DEUTERIUM AT TEMPERATURES BETWEEN -175°C AND +150°C. CONCLUSIONS FROM THE SECOND VIRIAL COEFFICIENT WITH REGARDS TO THE INTERMOLECULAR POTENTIAL.** A.Michels, W.de Graaff and C.A.ten Seldam. *Physica (Netherlands)*, Vol. 26, No. 6, 393-408 (June, 1960).

Values of the second and third virial coefficients of hydrogen and deuterium calculated from experimental PVT data and with the method of least squares and of the propagation of errors are presented in the temperature range from 150° to -175°C. Theoretical values of the second virial coefficient were calculated in the same temperature range, based on the Lennard-Jones potential field and on parameter values taken from literature, with corrections for the non-spherical part of the potential and for a number of quantum effects. Comparison shows that a satisfactory representation of the experimental data with a Lennard-Jones potential is impossible, even after adjustment of the parameter values to the experimental results. Additional information was obtained about the validity of the temperature scale.

- 6898 **THE SECOND VIRIAL COEFFICIENT OF BINARY MIXTURES OF THE HYDROGEN ISOTOPES AND HELIUM AT 20.4°K.**

H.F.P.Knaap, M.Knoester, F.H.Varekamp and J.J.M.Beenakker. *Physica (Netherlands)*, Vol. 26, No. 8, 633-7 (Aug., 1960).

The excess second virial coefficient,  $E$ , of binary mixtures of the hydrogen isotopes and helium was measured. The  $E$  for a mixture of a hydrogen isotope with He is quite large. There is reasonable agreement with the excess values derived from absolute measurements. For mixtures of the hydrogen isotopes, in agreement with theoretical predictions, no excess could be detected.

- 6899 **SECOND VIRIAL COEFFICIENT FOR THE MORSE POTENTIAL.**

D.D.Konowalow, M.H.Taylor and J.O.Hirschfelder. *Phys. of Fluids (USA)*, Vol. 4, No. 5, 622-8 (May, 1961).

Tables and algorithms are given for the classical second virial coefficient and its first two temperature derivatives for gases obeying a Morse potential  $\phi(r) = \epsilon(x^2 - 2x)$ , where  $x = \exp[-(c/a)(r - r_m)]$ . The calculations cover the temperature range  $0.3 \leq kT/\epsilon \leq 400$ .

- 6900 **ON THE VARIATION PRINCIPLE IN THE KINETIC THEORY OF DENSE GASES. I.** T.Murakami.

*J. Phys. Soc. Japan*, Vol. 15, No. 1, 60-9 (Jan., 1960).

The variation principle in the kinetic theory of gases is extended to the case of a dense gas of rigid-sphere molecules with finite radius. The solution of Enskog's first approximation equation for the dense gas of rigid-sphere molecules is derived from the variation principle. The local entropy production per unit time is maximum in this variational principle. The correction to the entropy due to imperfectness of the gas is calculated from the virial expansion of the equation of state for a rigid-sphere gas.

- 6901 **A SKETCH FOR A HISTORY OF THE KINETIC THEORY OF GASES.** E.Mendoza.

*Phys. Today (USA)*, Vol. 14, No. 3, 36-41 (March, 1961).

- 6902 **EQUATIONS OF MOTION OF A RAREFIED GAS.** M.N.Kogan.

*Priklad. Mat. i Mekh. (USSR)*, Vol. 22, No. 4, 425-32 (1958). In Russian.

After a brief review of the process by which the Navier-Stokes equations are obtained from the Maxwell-Boltzmann equation for relatively dense gases, the author undertakes an improvement for slightly rarefied gases. Here the right-hand side of the Maxwell-Boltzmann equation is written approximately as the difference between distribution functions, on the basis of a physical argument and a numerical verification for three simple cases. Although this was previously used by Bhatnagar, Gross and Crook (Abstr. 6360 of 1954), the present author has supplied the justification and concludes that the approximation is unsuitable for the particular case to which the earlier authors applied it. The equation is integrated and leads to a distribution function completely determined by the hydrodynamic quantities and their derivatives. All terms of Enskog's series are determined. For some cases in which the exact solution is known, the present method gives results correct in form but with slightly different constants. The paper closes with a remark concerning highly rarefied gases, wherein collisions are unimportant.

Mathematical Reviews

# EXTREME PRESSURES. II. VOLUME-TEMPERATURE RELATIONSHIP FOR GASES. L.S. Levitt.

J. chem. Phys. (USA), Vol. 34, No. 4, 1440-3 (April, 1961).

For Pt I, see J. phys. Chem. (USA), Vol. 58, 573 (1954). It is found, using Bridgman's data for  $H_2O$ ,  $N_2$ , and Ar, that the  $V-T$  isobars, though curved at medium pressures, become good straight lines at the same higher pressures for which the isothermal relation  $p = Ce^{B/V}$  begins to hold (above 1000 kg/cm<sup>2</sup> for gases, and above 4000 for liquids). Aside from the surprising linear variation of  $V$  with  $T$  under these extreme conditions, the most remarkable feature of the  $V-T$  plots is the apparent convergence of all the isobars (for a given gas) to a common intercept on the  $V$  coordinate (at 0°K). The isobars for gases therefore can be represented by the equation,  $V = V_0 + a_p T$ , where  $V_0$  is the incompressible molar volume of the substance at 0°K. Eliminating  $a_p$  for two different temperatures at constant pressure gives an exact  $V-T$  relation for high pressures comparable for Charles' law

$$V_2 = V_1(T_2/T_1) + V_0(1 - T_2/T_1).$$

The slope  $a_p$  of the isobars decreases with increasing pressure, and it is found that  $a_p \approx R'/p$ , where  $R'$  is a new gas constant for high pressures, which at first increases somewhat with pressure, and reaches the same limiting value of  $\frac{1}{2}R$  at 6000 atm for both  $N_2$  and Ar.

# 6904 THE EFFECT OF PRESSURES UP TO 5000 kg/cm<sup>2</sup> ON THE VELOCITY AND ABSORPTION OF ULTRASOUND IN NITROGEN. M.P. Volarovich and D.B. Balashov.

Dokl. Akad. Nauk SSSR, Vol. 135, No. 5, 1117-19 (Dec. 11, 1960). In Russian.

Pulse methods were used to study the effect of pressure on the velocity and absorption of 160 and 310 kc/s ultrasound at 20°C. The ultrasonic velocity rose with pressure; first more rapidly ( $v = 847$  and 1156 m/sec at 1000 and 2000 kg/cm<sup>2</sup>) and then more slowly ( $v = 1387$ , 1571 and 1723 m/sec at 3000, 4000 and 5000 kg/cm<sup>2</sup>, respectively). This was in agreement with Benedict's data (1937). The attenuation factor fell very rapidly between 0 and 1000 kg/cm<sup>2</sup> and then much more slowly between 1000 and 5000 kg/cm<sup>2</sup>. This fall was due to a sharp rise of the gas density and the velocity of ultrasound in it (viscosity, thermal conductivity and specific heat were less affected by increase of pressure). [English translation in: Soviet Physics-Doklady (USA)].

A. Tybulewicz

# MEASUREMENT OF RELAXATION TIMES OF GASES.

6905 M. Huetz-Aubert and J. Huetz.

J. Phys. Radium (France), Vol. 21, No. 1, 1-11 (Jan., 1960). In French.

For previous work, dealing with influences on ultrasonic propagation see Abstr. 14694 of 1960. Discusses the behaviour of di- or polyatomic gases in two cases: behind a shock wave front and during recompression in the vicinity of an obstacle.

# MOLECULAR THEORY OF LIGHT SCATTERING IN GASES AND LIQUIDS. See Abstr. 6965

# 6906 HIGH-TEMPERATURE ABSORPTION OF CARBON DIOXIDE AT 4.40 $\mu$ . M. Steinberg and W.O. Davies.

J. chem. Phys. (USA), Vol. 34, No. 4, 1373-7 (April, 1961).

The absorption of carbon dioxide-nitrogen mixtures at 4.40  $\mu$  was examined over a temperature range of 1200 to 2100°K for optical densities of 0.10 to 0.40 atm cm. The test gas was elevated to desired temperatures by shock compression. Properties of the test gas were determined by measurement of initial concentrations and shock-wave velocities. Absorption was observed as a diminution of source beam intensity monitored with a rapid response infrared detector and displayed on an oscilloscope. Beer's law was found to be applicable over the range of temperature and concentration studied. Absorption coefficients calculated from Beer's law plots reached a maximum of 3.0 atm<sup>-1</sup> cm<sup>-1</sup> about 1400°K, and were independent of total pressure from 0.26 to 1.05 atm. The absorption was also measured over a wavelength interval of 4.37 to 4.6  $\mu$ . The results of this investigation are compared to the existing theoretical and experimentally determined absorption data.

# PRESSURE DEPENDENCE OF FLUORESCENCE

6907 SPECTRA. D.J. Wilson, B. Noble and B. Lee.

J. chem. Phys. (USA), Vol. 34, No. 4, 1392-6 (April, 1961).

The pressure dependence of the fluorescence spectra of molecules in the gas phase is calculated for two models; one involving a strong collision mechanism of transferring vibrational energy, the

other involving a stepwise collision mechanism. The fluorescence spectra of the two models show very marked differences at pressures between the low pressure region of resonance fluorescence and the high pressure limit.

# LUMINESCENCE OF SOME ALIPHATIC ALDEHYDES AND KETONES IN THE VAPOUR PHASE AND IN DILUTE SOLUTION CRYSTALLIZED AT 77°K. P. Longin.

C.R. Acad. Sci. (France), Vol. 251, No. 22, 2499-2501 (Nov. 28, 1960). In French.

The emission spectra are similar and independent of the length of aliphatic chain, being due to the carbonyl group. Vibration spectra are seen only in aldehydes, and formaldehyde has a more resolved spectrum than the others.

S.T. Henderson

# 6909 ENERGY TRANSFER IN AROMATIC VAPOURS; THE BENZENE-SENSITIZED FLUORESCENCE OF ANTHRACENE VAPOUR AT 2652 Å. B. Stevens.

Disc. Faraday Soc. (GB), No. 27, 34-9 (1959).

"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 49 of 1961). The intensity of anthracene vapour fluorescence excited by the 2652 Å mercury line at 170°C is found to increase with the pressure of added benzene vapour. The lifetime of the excited anthracene molecule under these conditions is found from oxygen quenching measurements to be equal to the value found for the same molecule excited by the 3660 Å line, showing that no energy-dependent first-order deactivation of anthracene molecules takes place. Fluorescence enhancement in this case cannot therefore be due to collisional stabilization of the excited anthracene molecules, but must be due to energy transfer to anthracene from excited benzene molecules produced at this wavelength. The lifetime of the excited benzene molecule, determined from oxygen quenching measurements, together with the anthracene fluorescence intensity dependence on benzene pressure, enables a value of 7.6 Å to be calculated for the transfer distance.

# 6910 COMPARISON OF TWO METHODS OF MEASURING THE ELECTRICAL CONDUCTIVITY OF IONIZED AIR IN A SHOCK TUBE. P. Valentin.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 237-9 (Jan. 9, 1961). In French.

The two methods considered are the use of electrodes and the magnetic method, devised by Lin, Resler and Kantrowitz (Abstr. 2830 of 1955). New results of the author and earlier results due to Lamb and Lin (Abstr. 3196 of 1958) indicate that the agreement between the two methods is satisfactory.

N. Curle

# 6911 ELECTRICAL CONDUCTIVITIES OF THE CONSTITUENTS OF AIR UNDER THE ACTION OF A SHOCK WAVE. J. Thouvenin and R. Simonet.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 243-5 (Jan. 9, 1961). In French.

Comparisons were made of the electrical conductivities of air, nitrogen and oxygen in a shock tube, under the action of shocks of the same strength and temperature. It is found that the measured conductivity of the air is always greater than the value derived by adding 21% of the measured value for oxygen and 79% of the measured value for nitrogen. This finding is explained on the basis of the formation of nitrous oxide within the shock in air.

N. Curle

# 6912 COMPLEX CYCLOTRON RESONANCE IN DILUTE GASES. R.L. Collins.

J. chem. Phys. (USA), Vol. 34, No. 4, 1425-8 (April, 1961).

An X-band electron spin resonance spectrometer was used to analyse the products of an electrodeless discharge in flowing gases at low pressure. During a search for polyatomic free radical fragments, a multiple signal was found near  $g = 2.0000$ . Three poorly resolved peaks were found for a variety of paraffins and olefins, while methane, ammonia, methylamine, and sulphur dioxide yielded doublets. The structure was best resolved at low pressure. The spacing of the peaks increased with e.s.r. microwave power. Evidence is presented that the signal is caused by cyclotron resonance of photo-ionized electrons. It is suggested that this multiple resonance is more apparent than real, and arises from either a velocity-dependent capture process or from dephasing of electrons upon collision with gas molecules.

## VACUUM PHYSICS

- 6913 **SEMI-AUTOMATIC CONTROL OF VACUUM PUMPING SYSTEMS.** N.C.Balchin and B.L.Mordike.  
Vacuum (GB), Vol. 9, No. 5-6, 264-8 (Nov., 1959-Jan., 1960).

Describes a simplified control system which was developed for a small research vacuum system comprising rotary and diffusion pumps with a roughing line to the work chamber. The control system is claimed to be less expensive than the vacuum system and should be of value outside the research laboratory. F.A.Baker

- 6914 **SENSITIVITY OF VG-1A IONIZATION GAUGE CALCULATED FROM THE PROBABILITY OF IONIZATION OF GASES.** S.N.Ghosh and B.N.Srivastava.  
Canad. J. Phys., Vol. 39, No. 2, 373-9 (Feb., 1961).

Values of the sensitivity were calculated for He, Ne, A, H<sub>2</sub>, N<sub>2</sub>, CO, NO and CH<sub>4</sub>, and found to be in fair agreement with previously determined experimental values, except in the cases of CO, NO and CH<sub>4</sub>. J.Dutton

- 6915 **GREASELESS VACUUM VALVE USEFUL IN KINETIC STUDIES.** W.R.Doty and P.R.Ryason.  
Rev. sci. Instrum. (USA), Vol. 32, No. 1, 89-90 (Jan., 1961).  
A greaseless glass vacuum valve, employing an elastomer ("Viton-A") as the seat material and capable of operation up to 120°C, is described. The valve is particularly useful in gas reaction kinetics studies which involve the vapours of tetraethyl or tetramethyl lead, as this elastomer does not absorb these vapours and subsequently desorb them on further pumping. C.H.B.Mee

## VIBRATIONS . ELASTIC WAVES

(See also Shock Waves)

- 6916 **MAXIMUM POWER CRITERION FOR THE VIBRATING FREE EDGE DISK.** R.N.House, Jr.  
J. Acoust. Soc. Amer., Vol. 33, No. 5, 561-5 (May, 1961).  
A criterion for the maximum radiated power delivered by a high-efficiency piezoelectrically driven free disk, vibrating in the first symmetrical mode, has been developed. The maximum power emitted from such a transducer is necessarily limited by maximum stresses and strains to which the disk is subjected when undergoing transverse vibrations. A complete solution of the stress and strain distribution is given for this mode of vibration. Maximum values for these stresses and strains occur at the centre of the vibrating plate. Assignment of a safe stress level, dependent on material, which the centre of the vibrating plate must not exceed, then yields a unique value of maximum centre velocity at which disk fracture occurs. The maximum power criterion is then established by the maximum safe centre velocity, which is shown to be independent of plate geometry, and the radiation resistance of the disk in its operating medium. Experiment shows, as anticipated, that fracture occurs at the geometric centre of the vibrating plate, with power values consistent with the theory.

- 6917 **ON CORRELATING THE LOSS FACTORS OF CYLINDRICAL AND SPHERICAL RESONATORS.** P.D.Edmonds.  
J. Acoust. Soc. Amer., Vol. 33, No. 5, 615-22 (May, 1961).  
Theoretical results are presented which relate the Q factors (internal friction) of solid resonators to two loss parameters  $\lambda_1$  and  $\mu_1$ . The latter are assumed to be characteristic of the energy loss in the homogeneous, isotropic material constituting the resonators. Derivations start from the appropriate frequency — or velocity dispersion — equation in which complex elastic constants  $\lambda_r + j\lambda_i$  and  $\mu_r + j\mu_i$  are substituted. The following cases are treated: torsional, fundamental longitudinal and fundamental bending modes of solid cylinders, and radial modes of solid and hollow spheres. Deviations from constancy of Q are found in regions where velocity dispersion occurs. Computed results are tabulated which show the dependence of Q upon  $\lambda_1/\mu_1$  (range 0.1-10) and the propagation factor  $\tau$  (range -5 for cylinders); these apply to duralumin. Similar computations are used to interpret experimental results on polystyrene reported by Biesterfeldt, Lange, and Skudrzyk (see Abstr. 10707 of 1960), and an inconsistency is found in the values of  $\lambda_1$  calculated from the fundamental longitudinal and the fundamental bending modes of rods.

- 6918 **INPUT IMPEDANCE OF A BEAM COUPLED TO A PLATE.** G.L.Lamb, Jr.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 628-33 (May, 1961).  
The flexural vibration of an infinite elastic beam which is excited by a localized harmonic driving force and attached over its entire length to a thin elastic plate of infinite extent is investigated theoretically. The results are expressed in terms of two parameters,  $k_p L$  and  $r$ . The parameter  $k_p L$  describes the frequency dependence and degree of beam-plate coupling; and the parameter  $r$  is the ratio of flexural wave velocity on the plate to that on the beam. For  $r < 1$ , strong radiation into the plate is possible, while for  $r > 1$ , plate excitation is localized near the beam. In geometries of practical interest, the strong radiation case prevails. Small deviations in the input admittance of the beam from that of a free beam are initially obtained by employing a perturbation procedure which is valid in the limit  $k_p L \gg 1$ , the relevant range for geometries of practical concern. In addition, a variational principle for the admittance is constructed and shown to yield the results of the first-order perturbation solution when the displacement of a similarly excited free beam is used as a trial function. At very high frequencies the input admittance is found to approach that of a free beam, while at lower frequencies it is found that the plate adds an additional stiffness susceptibility to the input admittance. For a typical beam-plate geometry it is found that the beam is affected by the plate for all forcing frequencies below about 5000 c/s and may be estimated by the results of the present calculation down to a few hundred c/s.

- 6919 **THE SPATIAL RESOLUTION OF BARIUM TITANATE AND QUARTZ PLATES IN ULTRASONIC PICTURE FORMATION.** K.Hartwig.  
Acustica (Internat.), Vol. 9, No. 2, 109-17 (1959). In German.  
In connection with the use of piezoelectric plates as ultrasonic image converters measurements were made on BaTiO<sub>3</sub> plates of 0.3 to 1.2 mm thickness and on quartz plates of 0.4 to 1 mm thickness, within the frequency range 3.9 to 9.5 Mc/s. The distribution of amplitude over the surfaces of the plates when in forced vibration was measured, together with the frequencies of the natural vibrations of the plates. S.Weintraub

- 6920 **THE COUPLING FACTOR OF PIEZOELECTRIC CERAMIC DISKS.** D.S.Campbell and A.M.MacSwan.  
Brit. J. appl. Phys. Vol. 12, No. 4, 188-92 (April, 1961).  
Numerous formulae have been given for the calculation of the electromechanical coupling factor of piezoelectric disks in terms of the resonant and anti-resonant frequencies. These formulae, which are derived either on the basis of an analysis of the mechanical motions of a disk, or by considering the equivalent electrical circuit, give widely divergent values of coupling factor. It is shown that when an equivalent circuit which takes account of the overtones is used, the corresponding value of coupling factor obtained is in agreement with that of the mechanical analysis. Curves, and a nomogram are given to enable coupling factor to be quickly calculated from the equations of the mechanical analysis without approximation.

- 6921 **EXACT TRANSIENT SOLUTION OF SOME ELEMENTARY PROBLEMS OF ELASTIC WAVE PROPAGATION.** E.A.Flinn.  
J. Acoust. Soc. Amer., Vol. 33, No. 5, 623-7 (May, 1961).  
Two elementary problems of guided elastic wave propagation — a point source of SH waves in a free solid plate, and an arbitrary distribution of torsional stress across a normal section of a solid free cylinder — are considered, and exact transient solutions derived.

- 6922 **WAVE PROPAGATION ON BEAM-PLATE SYSTEMS.** M.Heckl.  
J. Acoust. Soc. Amer., Vol. 33, No. 5, 640-51 (May, 1961).

Formulae for the attenuation of bending waves that travel over a beam-plate system, containing one or several beams, are derived and compared with measurements. It is found that one beam gives an attenuation which is very small near the resonances of the beam and rather high elsewhere, but in the average over wide frequency bands the attenuation appears to go nearly like the square root of frequency. The addition of beams of the same material and dimensions does not give an appreciable increase in attenuation. Formulae for the force impedance and mean square velocity of beam-plate systems are also given. Finally, the damping of a beam by a plate attached to it is discussed.

6923 A METHOD OF INTEGRATION OF NONSTATIONARY LINEAR BOUNDARY-VALUE PROBLEMS CONCERNING THE PROPAGATION OF DISTURBANCES IN NON-IDEALLY ELASTIC MEDIA. E.I.Shemyakin. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 289-300 (1958). In Russian.

Treats waves generated by transient surface stress distributions in isotropic solids with dissipation effects.

6924 ON THE TRANSVERSE SHIFT ASSOCIATED WITH THE TOTAL REFLECTION OF MATTER WAVES.

H.Hara. Optik (Germany), Vol. 17, No. 8, 409-15 (Aug., 1960). In German.

The transverse shift of a bundle of waves reflected in the region of total reflection, which is well-known for electromagnetic and acoustic waves (Goos-Hänchen effect), is calculated for waves of matter. The Schrödinger wave equation enables a formulation to be made strictly in terms of a bundle of waves, whose width increases more rapidly than the magnitude of the shift of the rays as the critical angle of total reflection is approached. Furthermore, it emerges from the theory that a small difference in density between the adjoining media results in a fairly large shift, and it is pointed out that there is an analogous shift associated with the reflection of electromagnetic waves by the ionosphere.

6925 RESPONSE OF TWO-DEGREE-OF-FREEDOM SYSTEMS TO WHITE NOISE BASE EXCITATION.

A.J.Curtis and T.R.Boykin, Jr.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 655-63 (May, 1961).

The response is obtained analytically for a wide variation of the dimensionless parameters of the system. The interrelations of these parameters on the response are illustrated and shown to be very significant when the uncoupled natural frequencies of the system are of the same order. The limitations of approximation methods based on single-degree-of-freedom system or uncoupled two-degree-of-freedom system models are indicated. The applicability of the study to dynamic vibration absorber principles is evident. The responses are compared to previously published results.

## ACOUSTICS

PARAMETRIC EFFECTS IN MAGNETOACOUSTIC RESONANCE. See Abstr. 6408

6926 ACOUSTIC RADIATION PRESSURE BEARING. M.I.Seegall.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 566-74 (May, 1961).

A brief investigation is given of the concept of the acoustic bearing, the force of which is based on radiation pressure of a resonating sound wave. Of the principal configurations possible, a cylindrical geometry with plates on the ends of the cylinder was considered to be the most suitable. Output ratios of the order of 2640 d/w are shown to be obtainable. Experimentation reached a resonant amplification of 80; ways are shown by which amplifications of around 100 can be achieved. Beyond that internal absorption losses and cavitation present formidable obstacles which, at this point, cannot be overcome.

6927 CYLINDRICAL WAVE RECIPROCITY PARAMETER. R.J.Bobber and G.A.Sabin.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 446-51 (April, 1961).

A cylindrical wave reciprocity parameter  $J_c = (2/\rho c)(\lambda)^{1/2}L$  for use in a standard reciprocity calibration when the waves between the source and receiving transducers are cylindrical is derived from both four-terminal network theory and wave propagation theory. Experimental data from calibration measurements on underwater sound line transducers are presented to prove the validity of the parameter.

6928 ACOUSTIC INTENSITY ANOMALIES INTRODUCED BY CONSTANT VELOCITY GRADIENTS. M.A.Pedersen. J. Acoust. Soc. Amer., Vol. 33, No. 4, 465-74 (April, 1961).

Demonstrates by theoretical and numerical examples that in the calculation of ray-theory intensities in an underwater sound field the use of constant gradient layers can introduce spurious caustics and in some cases can omit real caustics. The theoretical intensity is discontinuous and becomes zero for a ray which is

horizontal at any layer interface where the slope of the velocity-depth function is discontinuous, not only for constant gradient layers but for any function which might be used to approximate the profile. If the slopes as well as velocities are continuous at a layer interface, the intensity will generally be continuous. The use of curved line segments preserving both velocity and slope continuity in the profile approximation is suggested.

6929 PULSE COMPRESSION IN AN ACOUSTIC WAVEGUIDE. K.Walther.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 681-6 (May, 1961).

Experiments on propagation and compression of pulses in an acoustic waveguide are described. A water filled channel of 32 ft length with pressure release surfaces is used as an acoustic waveguide with a cutoff frequency  $f_c = 13.5$  kc/s. Measurements on transient waveforms and on the dispersion curve of the guide in the frequency range between 13.5 and 26 kc/s are reported. In the pulse compression experiments the waveguide is used as a "match filter" with a frequency-dependent delay time. A frequency modulated input pulse of 12.6 msec length is compressed into an output pulse of shorter duration and of higher peak amplitude. The frequencies in the input pulse vary from 14 to 22 kc/s. A time compression ratio of 52.5 : 1 and a peak amplitude gain of 18.6 dB are achieved experimentally. The detection of a pulse in the presence of noise for an input signal to noise ratio of -20 dB is illustrated.

6930 ON THE RELATION BETWEEN THE REVERBERANT SOUND ABSORPTION COEFFICIENT AND THE NORMAL INCIDENCE ABSORPTION COEFFICIENT OF FIBROUS MATERIALS. M.Koyasu.

J. Acoust. Soc. Amer., Vol. 30, No. 12, 1163-4 (Dec., 1958).

FREQUENCY DEPENDENCE OF ULTRASONIC WAVE ATTENUATION IN ARMCO IRON AND LOW-CARBON STEEL. See Abstr. 6335

6931 FLOW RESISTANCE OF FIBROUS MATERIALS. D.A.Bies and P.A.Franken.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 695 (May, 1961).

An empirical relationship is developed for the flow resistance of a variety of fibrous materials.

6932 EFFECT OF AN INTERNAL WAVE ON SOUND IN THE OCEAN. O.S.Lee.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 677-81 (May, 1961).

A sound intensity field that is influenced by refraction of high frequency sound in a high-frequency internal wave is compared with the intensity field in the same medium with no internal wave, the thermocline. Ideal ocean mediums composed of three distinct layers are assumed for both cases. The surface layers have no sound velocity gradient, and the other two layers in both mediums are characterized by linear sound velocity gradients. Properties of the internal waves are similar to those observed off the coast at San Diego, California, in the summer months. The results show that narrow zones of high intensity and broad zones of low intensity alternately occur over a range as predicted by an earlier theory (Abstr. 132 of 1960). In the first case (no internal wave in the medium), contrasts in the intensity of about 5 dB occur over distances of one internal wavelength or less. In the second case (an internal wave in the medium), intensity contrasts of as much as 22 dB occur over the same distance.

6933 EFFECT OF DIFFRACTION ON VELOCITY OF SOUND. H.J.McSkimin.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 539 (April, 1961).

An addendum to a previous paper (Abstr. 19298 of 1960).

DIFFRACTION PATTERNS PRODUCED BY FINITE AMPLITUDE WAVES. See Abstr. 6964

6934 HIGHER ORDER-APPROXIMATION IN MULTIPLE SCATTERING. I. TWO-DIMENSIONAL SCALAR CASE. N.Zitron and S.N.Karp.

J. math. Phys. (USA), Vol. 2, No. 3, 394-402 (May-June, 1961).

The present paper deals with the diffraction of plane electromagnetic or acoustic waves by a pair of parallel cylinders of arbitrary shape. A formula is derived which expresses the perturbed scattering amplitudes of a combination of two arbitrary cylinders as a function of the unperturbed scattering amplitudes of the individual cylinders. The formula is valid when the spacing of the scatterers is large compared to their dimensions. It involves

derivatives of the scattering amplitudes with respect to the angles of incidence and of observation. Interaction terms of degrees  $d^{-1/2}$ ,  $d^{-1}$ , and  $d^{-3/2}$  are taken into account, where  $d$  is the spacing. Verification is obtained in a special case. The result is employed to calculate the total scattering cross-section. See also following abstract.

6935 HIGHER-ORDER APPROXIMATIONS IN MULTIPLE SCATTERING. II. THREE-DIMENSIONAL SCALAR

CASE. N.Zitron and S.N.Karp.

J. Math. Phys. (USA), Vol. 2, No. 3, 402-6 (May-June, 1961).

The method of Pt I (see preceding abstract) is extended to cover the three-dimensional scalar problem for two bodies of arbitrary shape. All interaction terms of order  $d^{-1}$  and  $d^{-2}$  are given.

6936 EXPERIMENTAL STUDY OF THE SCATTERING OF ACOUSTIC ENERGY FROM SOLID METAL SPHERES IN WATER. L.D.Hampton and C.M.McKinney.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 664-73 (May, 1961).

An experimental study of the scattering of acoustic energy from solid metal spheres in water was carried out in the frequency range 50-150 kc/s and with a range of sphere sizes from 1 to 7 in. in diameter, giving values of  $ka$  (acoustic radius) from 4.1 to 57. Data are presented which show the scattered pulse formation for pulses which are short compared to the sphere and for pulses which are long compared to the sphere as a function of frequency, of scattering angle, and of sphere composition. The study shows that the spheres cannot be treated as rigid bodies since an appreciable amount of energy penetrates the surface and results in a complicated echo structure for the scattered signal. The back-scattered target strength of spheres for short pulses (and considering only the surface-reflected pulse) is essentially constant with frequency for large  $ka$ , and is slightly less than the theoretical value for rigid spheres. For pulses which are long compared to the transit time across the sphere, the target strength fluctuates as much as 30 dB for small changes in frequency. For short pulses the angular distribution of the scattered energy is fairly uniform over the back  $180^\circ$ , but this is not true for long pulses.

6937 SUBJECTIVE EVALUATION OF MUSICAL SCALE TEMPERAMENT IN PIANOS.

D.W.Martin and W.D.Ward.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 582-5 (May, 1961).

It is known that standard procedures used by tuners results in a "stretched" scale (i.e. upper tones higher and lower tones lower than the equally tempered scale). Although there was anecdotal evidence of the desirability of this stretch (largely a natural consequence of tuning by beats) it had not been formally demonstrated. Therefore recorded tonal and chordal sequences from a small upright piano, tuned to a typical empirical stretched scale by means of a visual device, were compared with similar sequences from the same piano (1) tuned to strict equal temperament (again by means of the visual device), and (2) tuned by a factory "fine tuner" (by the conventional method). Strict equal temperament was unequivocally rejected both by musically oriented research engineers and by music students. Sequences covering the entire piano scale gave the most pronounced preferences.

6938 ULTRASONIC SPECTROSCOPY EMPLOYING CONTINUOUSLY VARIABLE FREQUENCIES.

R.Cerf, R.Zana and S.Candau.

C.R. Acad. Sci. (France), Vol. 252, No. 5, 681-2 (Jan. 30, 1961). In French.

In order to make absorption measurements over continuously variable frequency ranges the authors examine the response of a variable path-length interferometer working at frequencies on either side of the fundamental and harmonics of the transducing crystals. They conclude that satisfactory relative value of  $\alpha$  may be obtained. The specific absorption coefficient of a solution of polystyrene in benzene was determined up to more than 11 Mc/s using three crystals. A definite transition step is found to exist in the absorption-frequency curve, a characteristic not generally associated with relaxation phenomena.

J.D.Rands

KINETICS OF ULTRASONIC FOG FORMATION.

See Abstr. 6578

ULTRASONIC BEAM IN A WAVEGUIDE.

6939

F.Canac.

C.R. Acad. Sci. (France), Vol. 251, No. 22, 2489-91 (Nov. 28, 1960). In French.

The formation of diamond-shaped dark patches in schlieren pictures of ultrasonic beams reflected at an angle between two plane parallel plates is discussed. The number and shapes of these patches are calculated as functions of wavelength, plate separation and angle of incidence. Schlieren-type photographs are reproduced.

V.J.Hammond

## Instruments and Measurements

CONDENSER MICROPHONES WITH PLASTIC DIAPHRAGMS FOR AIRBORNE ULTRASONICS. II.

6940

K.Matsuzawa.

J. Phys. Soc. Japan, Vol. 15, No. 1, 167-74 (Jan., 1960).

For Pt I, see Abstr. 11965 of 1959. A detailed study was made of the condenser microphones with back plates, called "group IA" in Pt I of the present paper. For each back plate, the surface roughness is studied by using profilograms and the distribution function of the surface profile is obtained. Formulae for the resonance frequency, the electrostatic capacitance and the low-frequency sensitivity are obtained theoretically assuming a simple-model microphone with a back plate having a profile represented by the above distribution function. The formulae are found to be in fairly good agreement with the experiments.

RECIPROCITY CALIBRATION OF MICROPHONES IN A DIFFUSE SOUND FIELD. H.G.Diestel.

6941

J. Acoust. Soc. Amer., Vol. 33, No. 4, 514-18 (April, 1961).

Microphones can be calibrated by a primary technique in a diffuse sound field. The formula for the diffuse-field voltage response is derived from the well-known relationship for a reciprocal transducer in free space. It is shown that the reciprocity parameter for a diffuse-sound field follows from that for free space by replacing the distance by the "diffuse-field distance" of a point source. This distance depends only on the total absorption in the reverberation room. The experimental procedure is described in some detail and the results of the diffuse-field calibration of a Western Electric 640 AA condenser microphone are presented.

ACOUSTIC COMPUTER ELEMENTS. See Abstr. 6690

PHONON-PHOTON DOUBLE-QUANTUM TRANSITIONS AS A DETECTOR OF MICROWAVE ULTRASONICS. See Abstr. 6072

## OPTICS . PHOTOMETRY

THE BALLISTIC THEORY OF LIGHT.

6942

E.R.R.Holmberg.

Observatory (GB), Vol. 79, 223 (Dec., 1959).

Considers the proposed test of Bondi (ibid, Vol. 78, 237, 1958) and the discussion by Storey and Laurence (Abstr. 834 of 1960) of the theory by Dingle and suggests that they are in terms of phase velocity while Dingle is concerned with group velocity.

A RADIO-ASTRONOMICAL TEST OF THE BALLISTIC THEORY OF LIGHT EMISSION. H.Dingle.

6943

Observatory (GB), Vol. 80, 35-6 (Feb., 1960).

It is claimed that the proposed test is irrelevant as the problem is a purely kinematic one and cannot be settled by considerations depending upon relations between frequency and wavelength. Holmberg's distinction between group velocity and phase velocity (preceding abstract) is also dismissed as being purely hypothetical.

R.A.Newing

EXTENSION OF THE OPTICO-MECHANICAL

6944

ANALOGY. N.G.Chetaev.

Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 487-9 (1958). In Russian.

Establishes the analogy between Cauchy's mathematical theory of light and the stable motions of conservative and holonomic dynamic systems.

# 6945 PHOTOGRAPHIC REPRESENTATION OF BRIGHTNESS DISTRIBUTIONS. H.Greif.

Lichttechnik (Germany), Vol. 13, No. 2, 53-5 (Feb., 1961).  
In German.

The brightness (luminance) distribution in a visual field cannot be properly appreciated from an ordinary photograph. The author shows how, by using the techniques of equidensitometry, it is possible to produce a photograph with clearly defined boundary lines separating areas whose luminances are respectively above and below certain selected values, e.g. 1, 10, 100, 300 cd/m<sup>2</sup>, etc. The method is outlined and the necessary precautions are described.

J.W.T.Walsh

# GEOMETRICAL AND INSTRUMENTAL OPTICS SPECTROSCOPY

(Optical spectra and their analysis are included under the appropriate heading, e.g. Atoms, Molecules, Solid-State Physics, etc.)

# 6946 HIGH-SENSITIVITY RECORDING OPTICAL DENSITY METER. K.E.Collins and D.J.Steele.

J. sci. Instrum. (GB), Vol. 38, No. 5, 186-90 (May, 1961).

A recording optical smoke meter is described which has a high sensitivity. The optical density of smoke in a flue is compared by photoelectric means with that of an optical wedge, which is then rotated by an electrically operated servo-system until the two densities are the same. The angular position of the wedge is detected by a transducer, which provides a millivolt output proportional to the rotation of the wedge. A multi-channel switching unit, electrically coupled to a recorder, is incorporated; this enables any number of different flue units, up to the capacity of the recorder, to be used or other variables to be recorded at the same time. The range of the instrument can be varied by changing the value of the optical wedge in the balancing unit or by varying the transducer output to obtain full-scale deflection of the recorder for any desired rotation of the wedge. The calibration in terms of millivoltage output against optical density is linear, provided that the optical wedge and output transducer have linear characteristics. The output is stable to  $\pm 0.6\%$  of full-scale reading for ambient temperature changes in the range of 55-80° F, and the sensitivity is such that densities of the order of 0.005 can be recorded.

# 6947 PHOTOMETRY OF IMAGE CONVERTORS. G.Hansen.

SB Heidelberg Akad. Wiss. (math.nat.Kl.) (Germany), 1959, No. 5, 17-28. In German.

"Image convertors and storage tubes" meeting, Heidelberg, 1958 (see Abstr. 3004 of 1961). By means of an image convertor the luminance of an optical image can be increased in a calculable ratio. This principle may be applied to the photometry of optical instruments or to reduce the exposure needed to make a photograph. A description of the basic theory is given. The use of picture feedback is also described. A historical survey of the optical principle that no increase in the luminance of an object can be obtained by purely optical means is also given.

J.W.T.Walsh

# 6948 DETERMINATION, TO WITHIN $3 \times 10^{-10}$ SEC, OF THE INSTANT OF EMISSION OF A PHOTON IN THE VISIBLE REGION. B.Agrinier and A.Raviart.

C.R. Acad. Sci. (France), Vol. 252, No. 8, 1127-8 (Feb. 20, 1961).  
In French.

Measurements were made of the delay in response of a photo-multiplier tube, type 56 AVP, when actuated by a visible photon. The results show that this tube will give the instant of emission of such a photon to within  $3 \times 10^{-10}$  sec. The influence of the electrode potentials on the transit time of the tube was also investigated.

L.M.Roberts

# 6949 SHIFT OF THE SHADOW BOUNDARY AND SCATTERED CROSS SECTION OF AN OPAQUE OBJECT.

S.I.Rubinow and J.B.Keller.

J. appl. Phys. (USA), Vol. 32, No. 5, 814-20 (May, 1961).

When a wave of wavelength  $\lambda$  is incident upon an opaque object of typical dimension  $a$ , a shadow is formed in the geometric optics limit  $\lambda/a = 0$ . If  $\lambda/a$  is small and not zero, the shadow boundary is shifted slightly from the geometrical shadow boundary as was first shown by Artmann. He found the shift to be asymptotic to  $\alpha(\lambda^2/a)^{1/2}$  for a circular cylinder, where  $\alpha$  is positive or negative according to whether the field or its normal derivative vanishes on the cylinder. The same result was obtained by Rice for a parabolic cylinder, but for the hard cylinder his  $\alpha$  differed from Artmann's. The value of  $\alpha$  for the circular cylinder was redetermined and found to agree with the result for the parabolic cylinder in both cases. Also determined was the shift for a circular cylinder on which the field satisfies an impedance boundary condition. The former result is implicit in the work of Goriainov and both results are implicit in the work of Wait and Conda. The scattering cross-section of a circular cylinder with an impedance boundary condition was also determined. These results lead to two formulae, one for the shift of the shadow boundary and one for the scattering cross-section, of any smooth two- or three-dimensional object. The latter expresses the deviation from the geometrical optics cross-section as an integral, around a normal section of the shadow, of a multiple of the shift. This formula is verified for a sphere and for oblique incidence on a circular cylinder. Both electromagnetic and scalar waves are considered.

# 6950 THE CONTRAST TRANSMISSION FUNCTION FOR FIELD-GLASSES. A.Fürstner and H.Köhler.

Optik (Germany), Vol. 17, No. 8, 434-41 (Aug., 1960). In German.

The measurement of the contrast transmission function for binoculars with a minimum of experimental equipment is described. Results obtained with the moiré grating as suggested by Lohmann (Abstr. 1246 of 1959) are given.

# 6951 THEORY OF THE ACCURACY OF WEDGE DENSITY MATCHING OF LOGARITHMICALLY SECTORED SPECTRA. M.Green.

Appl. Spectrosc. (USA), Vol. 14, No. 4, 91-4 (1960).

An elementary theory on the accuracy of wedge-density matching for logarithmically sectored spectra is given. The results of the theory show that, other things being equal, the fractional error, as a result of wedge-density matching, in the measurement of intensity ratios of line pairs varies inversely as the intensity scale gamma of the emulsion employed, and within limits, is independent of both the magnification of the spectrum and the sector constant.

# 6952 A SMALL-GRATING SPECTROMETER FOR THE FAR INFRARED (45-150 $\mu$ ). P.Delorme and A.Hadni.

C.R. Acad. Sci. (France), Vol. 252, No. 9, 1299-301 (Feb. 27, 1961).

The spectrometer, which has a 68.6 mm square grating with 8 lines/mm, is described briefly, and its performance is illustrated by water vapour spectra. Spectra of the chloro- and bromonitrobenzenes are also included.

L.M.Roberts

# 6953 A SPECTROMETER FOR THE FAR INFRA-RED. R.H.Wright and P.N.Daykin.

Nature (GB), Vol. 189, 212 (Jan. 21, 1961).

A heated Nichrome coil and a Fresnel zone plate are mounted on opposite ends of a 4 m I-beam. The zone plate focuses the monochromatic image of the source directly on the bolometer element which moves along the axis of the instrument. The range is 30 $\mu$ -80 $\mu$ .

W.G.Jordan

6954 **AN ATOMIC BEAM SPECTROPHOTOMETER.**  
G.R. Isaak.  
Nature (GB), Vol. 189, 373-4 (Feb. 4, 1961).  
Describes the principle and method of use of a very high resolution instrument, which depends on Zeeman or Doppler scanning to move a narrow absorption line across the emission line under study, both lines being made narrow by using transverse observation of collimated atomic beams. J.Hawgood

6955 **MICROCELL FOR INFRARED STUDIES ON PURE LIQUIDS AT HIGH PRESSURES.**  
H.W.Schamp, Jr and W.G.Maisch.  
Rev. sci. Instrum. (USA), Vol. 32, No. 4, 414-15 (April, 1961).  
A small internal optical cell which can be used to study the infrared absorption of pure liquids to 12 000 atm is described. The sample is sealed in a small plastic bag which is held between two sapphire plates. The distance between the plates can be set to accommodate the different absorptive capacities of various liquids.

6956 **METHOD OF MODULATING A HIGH-INTENSITY SEARCHLIGHT.** J.R.Bibby.  
J. sci. Instrum. (GB), Vol. 38, No. 5, 194-5 (May, 1961).  
The construction of a rotating shutter for modulating the beam from a large military searchlight at 5-10 c/s is described, with notes on the modulated waveform produced. The searchlight was designed as a means of measuring the density of the atmosphere at heights between 30 km and 60 km, i.e. above the limit of normal radio-sonde measurements. The method was to direct a powerful searchlight beam upwards and measure the light scattered from it at various heights, by means of a photomultiplier.

6957 **TRANSISTORS AS HIGH-SPEED LIGHT PULSERS.**  
H.W.Kendall.  
IRE Trans nuclear Sci. (USA), Vol. NS-7, No. 2-3, 202-3 (June-Sept., 1960). [Proceedings of the Seventh Scintillation Counter Symposium, Washington, February, 1960].

The base-emitter and base-collector junctions of Si transistors type 2N696, 2N697, 2N699, 2N706 and 2N1132 were driven into avalanche breakdown with pulses (from a 50 ohm cable) having a rise-time of about 1 nsec and produced light pulses of similar rise-time; during each 4 nsec pulse about 80-200 photo-electrons were released from the photo-cathode of the photo-multiplier tube used to detect the light. Several hours pulsing at a pulse repetition frequency of 60 sec<sup>-1</sup> resulted however in the severe deterioration of most of the transistor junctions used. F.F.Roberts

**COLLIMATION OF ATOMIC BEAMS IN LIGHT SOURCES.**  
See Abstr. 5982

## PHYSICAL OPTICS

(*Luminescence is included under Solid-State Physics, Liquid State, or Gaseous State*)

6958 **A REFLECTING PHASE COMPENSATOR FOR OPTICAL MEASUREMENTS ON METALS.** M.M.Noskov.  
Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 3, 487-8 (1960). In Russian.

Describes the preparation and use of Cr, Nb, Ta and Pt mirrors as phase compensators in determinations of the optical constants of metals at infrared frequencies (by measuring the rotation of the plane of polarization on reflection of plane-polarized light by a mirror made of the metal being investigated). A.Tybulewicz

9959 **IRREGULARITIES IN EVAPORATED INTERFERENCE FILMS AND THEIR CONNECTION WITH LIGHT-SCATTERING.** G.Koppelman.  
Optik (Germany), Vol. 17, No. 8, 416-25 (Aug., 1960). In German.

Multiple-beam interferences were used to test the uniformity of dielectric layers produced by evaporation, the layers to be examined being the spacing layers of interference filters. Certain irregularities of film thickness, extending over microscopically small areas only, were detected. The scattering of light, caused by diffraction on these phase objects, is calculated, and it can be shown that this effect is of practical importance in exceptional cases only. However, irregularities of a different nature which may lead to a considerable scattering of light could also be observed. The cause of the irregularities is still virtually unknown.

6960 **APPLICABILITY OF COLOUR FILM FOR QUANTITATIVE MULTI-DIMENSIONAL COLOUR SCHLIEN ANALYSIS.** G.Heyl.

Ann. Phys. (Germany), Vol. 7, No. 5-6, 312-25 (1961). In German.  
With the arrangement of Wolter (see Abstr. 1003 of 1951) there is a correspondence between the chromaticity coordinates of the colour of the developed film and the direction and magnitude of the light bending by the schlieren object. This correspondence can be determined for a given illuminant, polarization device, schlieren geometry and colour film. Examples of the method are given. W.T.Welford

6961 **ANALYSIS OF DOUBLE ANTI-REFLECTION LAYERS.**  
H.Vonarburg.

Optik (Germany), Vol. 17, No. 8, 426-33 (Aug., 1960). In German.  
It is well known that the simple anti-reflection layer of thickness  $\lambda_0/4$  (where  $\lambda_0$  is a wavelength approximately in the middle of the observed frequency band), inserted between materials with different refractive indices, produces a minimum of reflection only at the point of the range of visible light corresponding to  $\lambda_0$ . The reflected part of the energy increases on each side of this point  $\lambda_0$  according to an approximately parabolic function. Double layers of suitable thickness and correctly chosen refractive indices give — ignoring absorption — two zero points for the reflection. In the present paper, formulae are deduced for the refractive indices and thicknesses of the two interference layers, neglecting absorption and assuming normal incidence of the waves. Electrical transmission theory is used in the course of this analysis; for there is an analogy between the optimum energy delivered by a generator through a high frequency cable to a consumer, and this optical problem. As an example of the application of the theory, a transfer from air to glass is calculated.

**RESONANT MODES IN AN OPTICAL MASER INTERFEROMETER.** See Abstr. 7143

6962 **DIFFRACTION BY AN IRREGULAR SCREEN OF LIMITED EXTENT.** B.H.Briggs.

Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 305-17 (Feb., 1961).  
The problem considered is the nature of the diffraction pattern produced by an irregular diffracting screen of limited extent. In particular, the deductions which may be made about the screen from measurements of the correlation of the wave disturbances at separated points in the diffraction pattern are discussed. It is shown that such measurements can give information about either the size of the irregularities in the screen or about its overall extent depending on the distance from the screen at which the measurements are made. Close to the screen, the measured auto-correlation function of the diffraction pattern is shown to be the same as that of the small scale irregular structure in the screen. Observations of this function can, therefore, be used to determine the size of the irregularities in the screen. Far from the screen this is no longer true, and the auto-correlation function is determined by the angular distribution of power over the screen as seen from the observing point; it is in fact equal to the Fourier transform of this angular power distribution. Measurements made at a large distance, therefore, give no information about the small scale structure of the screen, but can be used to determine the distribution of power over it. The distance from the screen at which the transition takes place may be calculated by multiplying the size of the small irregularities by the overall length of the screen, and dividing by the wavelength of the radiation. If nothing is known about the nature of the screen or its distance, it is impossible to decide upon the correct interpretation of the measurements. However, in most experiments enough is known to enable the correct interpretation to be made. Several examples are discussed including measurements of the angular diameter of stars, measurements of the small scale structure of the ionospheric layers, and the problem of reflection from irregular ionized trails produced by meteors. See also following abstract.

6963 **DIFFRACTION BY FINITE IRREGULAR OBJECTS.**  
R.P.Mercier.

Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 318-27 (Feb., 1961).  
Gives a theory of statistical correlation in the complex amplitude of a scalar wave diffracted by an irregular object of limited extent. The theory is one-dimensional, and uses the Fresnel integral to calculate the amplitude at the receiver. Two well-known results appear as special cases. In the first the correlation function of the complex amplitude in the wave is shown to be the same as the correlation function of the complex amplitude at the object if the

object is an infinite plane; this is the basis of irregularity measurement in the ionosphere. In the second the correlation function of the complex amplitude is shown to depend upon the angular distribution of mean power over the source. This is the basis of the Michelson method for measuring the angular diameter of a star. The criterion which distinguishes between the two cases is expressed in terms of the overall size of the object, the irregularity size, the wavelength and the distance from the object. The similar case of diffraction by a cylindrical object is considered. Here, the criterion distinguishing the two cases involves only the irregularity size and wavelength. An application to lunar radio echoes is discussed, and it is concluded that the irregularities in the lunar surface cause phase fluctuations much greater than one radian, and these phase fluctuations are correlated over a distance of some 15 metres. See also preceding abstract.

#### 6964 DIFFRACTION PATTERNS PRODUCED BY FINITE AMPLITUDE WAVES.

M.A.Breazeale and E.A.Hiedemann.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 700-1 (May, 1961).

Pictures are given which illustrate in detail the optical effects produced by ultrasonic waves of finite amplitude in liquids. These effects can be used for the analysis of the wave form.

#### 6965 A MOLECULAR THEORY OF LIGHT SCATTERING IN GASES AND LIQUIDS. S.Kielich.

Acta phys. Polon. (Poland), Vol. 19, No. 2, 149-78 (1960).

The general principles of a statistical-molecular theory of light scattering in an isotropic medium consisting of polar-anisotropic molecules are given.

#### 6966 APPARATUS FOR THE MEASUREMENT OF LIGHT SCATTERING IN LIQUIDS. MEASUREMENT OF THE RAYLEIGH FACTOR OF BENZENE AND OF SOME OTHER PURE LIQUIDS. D.J.Coumou.

J. colloid Sci. (USA), Vol. 15, No. 5, 408-17 (Oct., 1960).

The construction of an apparatus for measuring the scattering of light in colloidal solutions and its angular dependence is described. The optical part is designed in such a way that the photometer measures the flux of scattered light originating from a well-defined volume of liquid within a well-defined solid angle. The intensity of the scattered light is compared with a part of the primary beam in a compensator with a sensitive null-amplifier. For comparing fluxes of light scattered in different media the corrections for volume and solid angle can be combined into one refractive-index correction. Its value, for cylindrical as well as for rectangular liquid cells, is equal to the square of the ratio of the refractive indices. Absolute measurements of the Rayleigh factor of benzene with a precision of about 2.5% were made using light of three different wavelengths. Rayleigh factors of some other pure liquids were also determined. The value of Avogadro's number calculated from these results with the aid of the Einstein formula shows the reliability and accuracy of the instrument for absolute light-scattering measurements.

#### POLARIMETRIC METHOD OF MEASURING SMALL ROTATIONS. See Abstr. 6818

#### 6967 ON A NEW METHOD OF STUDYING ULTRASHORT SCINTILLATIONS. Y.Koechlin.

C.R. Acad. Sci. (France), Vol. 252, No. 3, 391-3 (Jan. 16, 1961). In French.

The method described consists of determining the distribution in time, with respect to a precisely defined origin, of the photons emitted. The use of a 56 AVP photomultiplier allows one to apply the method to a study of the "shape" of the scintillations (number of photons versus time) with a precision of  $0.27 \times 10^{-9}$  sec.

J.L.Redding

## COLORIMETRY . PHOTOGRAPHY

#### 6968 KERR CELL FRAMING CAMERA. W.C.Goss.

J. Soc. Motion Picture Televis. Engrs (USA), Vol. 69, No. 12, 889-91 (Dec., 1960).

The design of a high-speed Kerr cell framing camera is described. A single Kerr cell, pulsed once, is used in conjunction with a system of optical delays to provide six consecutive pictures at interframe times of  $1.5 \times 10^{-8}$  sec and exposure times of  $5 \times 10^{-9}$  sec. The camera is f/10 at the 35 mm film plane and the pictures have

roughly  $240 \times 600$  information lines content. Source image threshold energy is expected to be at an effective blackbody temperature of  $\sim 0.5$  eV for Tri-X film.

#### 6969 PHOTOGRAPHIC TECHNIQUE FOR THE DETERMINATION OF METAL CUTTING TEMPERATURES. G.Boothroyd.

Brit. J. appl. Phys., Vol. 12, No. 5, 238-42 (May, 1961).

An experimental technique was developed for the measurement of the temperature distribution in the deformation zone and in the chip and tool during orthogonal cutting. The term orthogonal cutting is used for the special case where the cutting edge of the tool is perpendicular to the direction of relative motion of the workpiece and tool. The method involves photographing the chip, tool and workpiece in a plane perpendicular to the cutting edge, using an infrared sensitive photographic plate. The optical density of the plate is determined over the relevant field by means of a microdensitometer. A heated tapered strip, on which the temperature distribution is measured by means of a series of thermocouples, is photographed simultaneously with the tool and workpiece. This enables the optical density of the plate to be calibrated in terms of temperature, and the temperature distribution over the chip, tool and workpiece can hence be determined. The effect of surface emissivity and of other factors on the accuracy of the technique are considered, and the results of an experiment using the photographic technique are presented and discussed in relation to previous theoretical and experimental work.

#### APPLICABILITY OF COLOUR FILM FOR QUANTITATIVE MULTI-DIMENSIONAL COLOUR SCHLIEREN ANALYSIS. See Abstr. 6960

#### PHOTOGRAPHIC REPRESENTATION OF BRIGHTNESS DISTRIBUTIONS. See Abstr. 6945

## HEAT . RADIATION

#### 6970 THE APPLICATION OF ANALOGUES TO THE SOLUTION OF HEAT-TRANSFER PROBLEMS. I. HISTORICAL DEVELOPMENT OF ANALOGUES BASED ON EXAMPLES. J.A.Knobbout.

Ingenieur (Netherlands), Vol. 73, No. 3, O.43-O.51 (March 10, 1960). In Dutch.

Stationary phenomena are discussed with particular reference to the "film" analogue for temperature distribution; this led to the development of Teledeltos electrically conducting paper for the study of temperature fields. The electrolytic trough in its early forms and present developments, and electrical resistor-network analogues are then considered. Under non-stationary phenomena, the Beuken model (1936), the hydraulic analogue, the resistance analogue of Liebmam (1950) and analogues with active elements are discussed. The use of analogues for studying the behaviour of stationary and non-stationary heat exchangers and the possibility of establishing the non-stationary behaviour of thermodynamic cycles are then examined. A bibliography of 40 items is given.

G.N.J.Bel

#### 6971 A NEW TYPE OF THERMAL CONDUCTIVITY GAS DETECTOR. I. S.Sôma and Y.Takeuchi.

J. Phys. Soc. Japan, Vol. 15, No. 2, 333-6 (Feb., 1960).

A new type of gas detector with two thermistors and two thermistor-cells was designed. Two thermistors were enclosed in each thermistor-cell respectively, one of the cells having a porous window through which gases may run into the cell from the outside. By measuring the thermal conductivity of any gas permeating into the cell through the porous window, it can be detected with high sensitivity. Since the cell is small, the time response is rapid, and the sensitivity is increased due to the self-heating effect of the thermistor. Using this method, 0.01% hydrogen contained in air was detectable.

#### 6972 A SIMPLE METHOD OF DETERMINING THE THERMAL CONDUCTIVITY OF SOLIDS. J.Schröder.

Philips tech. Rev. (Netherlands), Vol. 21, No. 12, 357-61 (1959-60). The two ends of a cylindrical sample, about 18 mm in diameter and 0.5-30 mm in length, are kept at constant temperatures, by contact with two boiling liquids of suitable boiling points, viz. differing by about 10°C. The time is measured in which a quantity of heat flows, in the steady state, through the sample. This quantity

s fixed very simply by the evaporation of a fixed quantity of liquid at the "cold" end, collected as condensate. In practice, two calibrated samples are measured first and a calibration line is plotted from which the thermal resistance of subsequent samples can be found at a glance. It is then not necessary to know the exact boiling points of the two liquids, nor the absolute quantity of evaporated liquid, nor its heat of vaporization. A measurement takes 5 to 15 minutes and the error is not more than  $\pm 3\%$ . With some additional equipment the method can also be used for measurements at other than room temperature, between  $-200$  and  $+400^\circ\text{C}$ .

- 6973 **EXPERIMENTAL STUDY OF HEAT TRANSFER WITH GASEOUS HYDROGEN IN TURBULENT FLOW IN A TUBE AND IN AN ANNULAR SPACE (WITH SMOOTH WALLS).** A. de La Harpe and P. Perroud. C.R. Acad. Sci. (France), Vol. 252, No. 3, 385-7 (Jan. 16, 1961). In French.

The authors have sought to modify Colburn's formula for heat transfer. An analysis of experimental results was made, for wall temperatures  $T_p$  of  $100$  to  $700^\circ\text{C}$  and hydrogen temperatures  $T_m$  at the inlet of  $10$  to  $200^\circ\text{C}$ , and at Reynolds numbers  $Re$  of about  $120\,000$  for the tube and  $50\,000$  for the annular spaces. Amended definitions of Reynolds number, Prandtl number  $Pr$  and Nusselt number  $Nu$  lead to a formula  $Nu = CRe^{0.6}Pr^{0.4}$ , where  $C (=0.023$  in Colburn's formula) is a function of flow geometry and the modified definitions depend upon an empirically determined intermediate temperature.

N. Curle

**HEAT FLUX IN REACTING GAS MIXTURE.** See Abstr. 6567

- 6974 **NONSTATIONARY THERMAL CONVECTION IN A SPHERICAL LAYER.** I.G. Sevruck. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 3, 419-23 (1958). In Russian.

- 6975 **TRANSIENT THERMAL CONVECTION IN A SPHERICAL CAVITY.** S.P. Pustovoit. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 568-72 (1958). In Russian.

- 6976 **LAMINAR CONVECTION OVER A LINEAR HEAT SOURCE.** I.G. Sevruck. Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 4, 573-6 (1958). In Russian.

- 6977 **DISCONTINUITY PROPERTIES OF LAMINAR FLAMES.** T. Maxworthy. Phys. of Fluids (USA), Vol. 4, No. 5, 558-64 (May, 1961).

An experimental investigation was made to test the basic hypotheses of published infinite and finite two-dimensional flame front theories, in which the flame is considered to be a surface of discontinuity, in properties, between reactant and product flow fields. The "particle track" method was used, in which a controlled quantity of magnesium oxide particles was introduced into the flow; these were illuminated stroboscopically and the resultant "particle paths" recorded photographically. The results show deviations from the theoretical predictions, due to secondary effects not considered by the theories. For example, the effect of the finite width and thickness of the flame, effect of energy losses from the flame edges, effect of losses due to instabilities inherent in the flames studied.

**RADIATIVE HEAT TRANSFER FROM A DENSE HIGH-TEMPERATURE PLASMA.** See Abstr. 7052

- 6978 **USE OF  $\text{PrCl}_3$  IN A SOLID STATE INFRARED QUANTUM COUNTER.** J.F. Porter, Jr. J. appl. Phys. (USA), Vol. 32, No. 5, 825-6 (May, 1961).

A survey of the salts of the rare-earth series shows that anhydrous  $\text{PrCl}_3$  has energy levels and selection rules suitable for use in a solid state infrared quantum counter as proposed by Bloembergen (Abstr. 6281 of 1959). Two suitable schemes are proposed, one for detection at  $2.33\ \mu$  and a second for detection at  $104\ \mu$ . Consideration is given to isolation of the final detector from the pumping signal and a suitable experimental arrangement for unambiguously determining proper operation is shown.

- 6979 **THE COLOUR-TEMPERATURE OF AN INCANDESCENT HELICAL FILAMENT.** J.E. Gibbs and G.W. Gordon-Smith. Brit. J. appl. Phys., Vol. 12, No. 5, 257-9 (May, 1961).

Spectrophotometric measurements at  $0.54$  and  $0.69\ \mu$  of the radiation from the "inside" and the "outside" of the helical filament of a  $12\ \text{V}$ ,  $48\ \text{W}$  car bulb run at  $4\ \text{A}$  show that, owing to multiple

reflection within the helix, the luminance of the inside is about  $70\%$  greater, and its colour-temperature  $50 \pm 1\ \text{deg K}$  lower, than that of the outside. The colour-temperature of the integrated light from a helical filament depends critically on the angular position of the receiver relative to the source. Irregular variations of about  $10\ \text{deg K}$  were measured within  $\pm 10^\circ$  of the equatorial plane of the filament mentioned, and similar variations for a  $100\ \text{V}$ ,  $500\ \text{W}$  uniplanar projection lamp. Caution is indicated in using such lamps as standards of colour-temperature.

- 6980 **PHOTOELECTRIC OPTICAL PYROMETER.** J. Middlehurst and T.P. Jones. J. sci. Instrum. (GB), Vol. 38, No. 5, 202-4 (May, 1961).

An optical pyrometer is described in which the brightness match is performed photoelectrically. A sensitivity of  $\pm 0.02\ \text{deg C}$  at  $1063^\circ\text{C}$  is achieved with a reproducibility of  $\pm 0.1\ \text{deg C}$ .

- 6981 **STABILIZATION OF THERMOMETERS OF BOROSILICATE GLASS FOR USE AT HIGH TEMPERATURES.** J.A. Hall and V.M. Leaver. J. sci. Instrum. (GB), Vol. 38, No. 5, 178-85 (May, 1961).

An investigation has been made into the best heat-treatment to be given to thermometers of borosilicate glass before graduation, in order to secure good stability in use at temperatures between  $400$  and  $500^\circ\text{C}$ . Zero rises of less than  $0.1\ \text{deg C}$  per  $100\ \text{hr}$  at  $460^\circ\text{C}$  have been achieved by a stabilization treatment consisting of cooling from  $570$  to  $410^\circ\text{C}$  in not less than  $400\ \text{hr}$ . No shorter treatment gave as good a result if the thermometers were used above  $410^\circ\text{C}$ . A comparison is made of the performances of three glasses, of German, American and English origin.

- 6982 **INDIUM RESISTANCE THERMOMETERS.** B. Yates and C.H. Panter. J. sci. Instrum. (GB), Vol. 38, No. 5, 196-7 (May, 1961).

A description is given of the construction of an indium resistance thermometer, which is particularly suitable for use in cryostats where working space is limited. The ice point resistance of the thermometer changed by less than five parts in  $30\,000$  after repeated cooling to  $14^\circ\text{K}$ . Mathematical representations of the variation of resistance with temperature are given for the greater part of the temperature range  $14$  to  $323^\circ\text{K}$ .

- 6983 **OXIDE RESISTOR FURNACE FOR HIGH-TEMPERATURE OPERATION.** E. Rothwell. J. sci. Instrum. (GB), Vol. 38, No. 5, 191-3 (May, 1961).

A thorium-base oxide resistor furnace was constructed for operation at temperatures up to  $2400^\circ\text{C}$  in an oxidizing atmosphere. The maximum temperature attainable is limited by the ionization of the air in the vicinity of the oxide resistor, and simple means of overcoming this limitation are suggested. The furnace may prove attractive for some specialized investigations, where the requirement of an oxidizing atmosphere is sufficient to override the inherently fragile nature of the resistor element.

- 6984 **VACUUM RADIATION FURNACE WITH PRECISE CONTROL OF TEMPERATURE GRADIENTS FOR CRYSTAL GROWTH BY SUBLIMATION.** A.C. Prior. J. sci. Instrum. (GB), Vol. 38, No. 5, 198-201 (May, 1961).

The furnace was designed for the growth of lead selenide single crystals at  $775^\circ\text{C}$ . It provides an inherently high degree of temperature uniformity and, without the use of a servo control system, the gradients can be adjusted and maintained to less than  $0.1\ \text{deg C cm}^{-1}$  and  $0.25\ \text{deg C in } 10\ \text{cm}$ . A changed gradient can be established in 5 minutes. In heating from cold a steady temperature is attained in 75 minutes, and the furnace can be cooled in a few minutes. This performance is achieved by minimizing the total mass of heated material, and by the use of highly reflecting water-cooled silvered surfaces for the walls. An outline is given of the regulating system for controlling the absolute temperature to  $0.1\ \text{deg C}$ . Evaporation of the alloy heater element limits the maximum temperature to about  $940^\circ\text{C}$ , but this should be raised by the use of other elements.

- 6985 **ELIMINATION OF A GLOW DISCHARGE IN AN INDUCTION-HEATED VACUUM FURNACE.** J.E. Fagel. Nature (GB), Vol. 189, 212-13 (Jan. 21, 1961).

Troublesome glow discharges in induction heated vacuum furnaces were easily removed, and at little expense, by the use of a small permanent magnet placed near the glass wall of the furnace.

H. Edels

6986 A PLASTIC CAPSULE TECHNIQUE FOR THE COMBUSTION CALORIMETRY OF VOLATILE OR CHEMICALLY REACTIVE COMPOUNDS: THE HEAT OF COMBUSTION OF POLYTHENE. H.Mackle and R.G.Mayrick. J. sci. Instrum. (GB), Vol. 38, No. 5, 218-20 (May, 1961).

A technique for vacuum-forming polythene capsules for use in the combustion calorimetry of volatile or chemically reactive compounds is described. It has a number of advantages over the glass-ampoule method. Values for the heat of combustion of polythene are reported.

6987 TIME INTERVAL IN THE CLEMENT AND DÉSORMES EXPERIMENT.

R.H.Magarvey, R.L.Bishop and B.L.Blackford. Amer. J. Phys., Vol. 29, No. 4, 274-5 (April, 1961).

This experiment serves to determine the ratio of the specific heats  $c_p/c_v$  of a gas from pressure readings obtained before and after an adiabatic expansion. It is pointed out that the time allowed for this expansion is important. P.T.Landsberg

## CHANGE OF STATE

(Solid-state phase transformations are included primarily under Structure of Solids)

6988 HEATING AND MELTING OF A SOLID DUE TO FRICTION. S.S.Grigoryan.

Priklad. Mat. i Mekh. (USSR), Vol. 22, No. 5, 577-85 (1958). In Russian.

Two problems are considered: friction between two solids and friction between a solid and a viscous incompressible liquid which flows round it. Theoretical.

EFFECT OF PRESSURE ON THE MELTING POINT OF InSb. See Abstr. 6160

THE GROWTH OF DROPLETS: PROGRESS REPORT No. II (FINAL). See Abstr. 6849

## THERMODYNAMICS

(See also Statistical Mechanics)

6989 THREE DIMENSIONAL PRESSURE TEMPERATURE ENTROPY DIAGRAM. P.M.Boatman.

Proc. Iowa Acad. Sci. (USA), Vol. 67, 431-6 (1960).

Three properties of carbon dioxide, namely, pressure, temperature, and entropy, are combined to produce three graphical plots: (1) Pressure versus Temperature, (2) Entropy versus Temperature, and (3) Entropy versus Pressure. These three plots are, in actuality, the three projections of a three-dimensional surface depicting all the phases of carbon dioxide. The fluid must exist on the surface at all times, and any thermodynamic process will occur along the surface. The general configuration of the three-dimensional surface for carbon dioxide is shown, and the areas depicting structures are labelled.

## LOW-TEMPERATURE PHYSICS

LEV DAVYDOVICH LANDAU WINNER OF THE SECOND FRITZ LONDON AWARD. See Abstr. 6758

## Liquid and Solid Helium

6990 GROUND STATE OF LIQUID HELIUM (MASS 4). Fa Yueh Wu and E.Feenberg.

Phys. Rev. (USA), Vol. 122, No. 3, 739-42 (May 1, 1961).

The wave-function describing the ground state of a boson system is approximated by the function  $\Psi = \Pi \exp[\frac{1}{2}u(r_{ij})]$ . The superposition approximation is then used to derive a linear, inhomogeneous integral equation for  $du/dr$  in which the only other quantities occurring are the experimentally observed two-particle distribution

function  $g(r)$  and its first derivative. A numerical solution for Helium is computed and compared with the explicit approximation solution derived by Abe (Abstr. 12546-7 of 1960). Using the computed  $u(r)$  and a proper smooth extrapolation of  $g(r)$  into the region below the apparent cutoff at  $r = 2.34 \text{ \AA}$ , the kinetic energy of liquid  $\text{He}^4$  at absolute zero is estimated at  $2.91 \times 10^{-15} \text{ ergs/atom}$ . A functional  $J(du/dr)$  is constructed with the property that Abe's integral equation for  $du/dr$  is just the Euler equation associated with the problem of finding a  $u$  for which  $J$  takes on an extreme value. The extreme value of  $J$  (actually a maximum) is simply related to the expected value of the kinetic energy. The variational property is used to determine the best  $u(r)$  from a family of trial functions. The calculated value of the kinetic energy and the measured total energy are used, in conjunction with the virial theorem, to determine the coefficients of a 6-n Lennard-Jones potential. At  $n = 12$ , the calculation yields a deeper potential well and a slightly wider repulsive region than is calculated from the properties of the gas phase.

6991 VISCOSITY OF LIQUID  $^3\text{He}$ - $^4\text{He}$  MIXTURES IN THE HELIUM II REGION ABOVE  $1.0^\circ \text{K}$ .

F.A.Staas, K.W.Taconis and K.Fokkens.

Physica (Netherlands), Vol. 26, No. 9, 669-86 (Sept., 1960).

The viscosity of liquid  $\text{He}^3$ - $\text{He}^4$  mixtures is derived from isothermal flow through a capillary  $75.6 \mu$  in diameter. The apparatus consists of two identical glass vessels, connected to each other by the glass capillary. The positions of both levels were measured as a function of time. It appeared that the logarithm of the level difference always decreased linearly with time, which means that Poiseuille's law is obeyed. The analysis of the flow has been given. The values of the viscosity extrapolated to zero concentration (pure  $\text{He}^3$ ) are in agreement with the measurements with the rotating cylinder by Heikkila and Hollis Hallett. There is also satisfactory agreement in the low concentration region with the theory given by Zharkov.

6992 HYDRODYNAMIC DRAG ON SPHERES MOVING IN LIQUID HELIUM. R.A.Laing and H.E.Rorschach, Jr.

Phys. of Fluids (USA), Vol. 4, No. 5, 564-71 (May, 1961).

The drag coefficient of spheres falling in liquid helium I and in some ordinary fluids for Reynolds numbers between  $10^4$  and  $3 \times 10^6$  was measured. The values of the drag coefficient and the size of the wall corrections for helium I agree with the helium II results and with the results obtained for ordinary fluids. The drag crisis in liquid helium is postponed, but this can be explained by a small value of its kinematic viscosity and the dynamics of boundary layer formation. This agreement suggests that helium I and helium II can be described at high Reynolds numbers by a single velocity field satisfying a Navier-Stokes equation.

6993 HYDRODYNAMICS OF HELIUM II IN ANNULAR GEOMETRY. P.J.Bendt and T.A.Oliphant.

Phys. Rev. Letters (USA), Vol. 6, No. 5, 213-15 (March 1, 1961).

The flow of  $\text{He}^4$  is considered in a rotating annulus of circular frequency  $\omega$ , inner radius  $r_1$  and outer radius  $r_2$ . Minimizing the free energy, it is found that the velocity field of the superfluid is different inside and outside a certain boundary of radius  $r_a$ . For  $r > r_a$  one has the quasi-solid body rotation assumed for singly connected containers, the microstructure of which consists of a uniform array of vortex lines parallel to the axis of rotation, each having the circulation  $h/m$  ( $m = \text{mass of a helium atom}$ ). In the region  $r_1 < r < r_a$  the flow is irrotational with a discontinuity of velocity at  $r = r_1$ . Two possibilities are considered for the boundary at  $r = r_a$ , viz. either stipulating continuity of velocity or ignoring this boundary condition. In the latter case a further reduction of free energy is obtained by adjusting the circulation of the inner region. For a certain value of  $\omega r_1^2$  (which is 0.1 or  $0.4 \text{ cm}^2/\text{sec}$  respectively if  $r_2/r_1 = 1.1$ )  $r_a$  reaches  $r_2$ . For lower  $\omega$  the flow is irrotational throughout. At the discontinuities slip planes are provided by vortex lines close to the boundaries. Their number is such that it is possible to demarcate the irrotational region by closed rectangular vortex lines. When the flow is irrotational in the whole annulus the circulation is no longer determined by the rotation of the container which could be brought to rest leaving a persistent current of superfluid.

H.London

6994 THEORY OF SOLID  $\text{He}^4$ . L.Goldstein.

Phys. Rev. (USA), Vol. 122, No. 3, 726-38 (May 1, 1961).

Using a phenomenological approach, it is shown first that solid  $\text{He}^4$  in equilibrium with liquid  $\text{He}^4$  II along the phase separation line as well as at pressures somewhat above the melting pressure, should have anomalous thermal properties over a finite temperature range or, at least, at isolated temperatures. Such a behavior

of the solid results from a correlation of thermodynamic character of its thermal properties with those of the anomalous liquid. The predicted anomalies of the solid are effectively verified in terms of rigorous thermodynamics and somewhat incomplete data available on liquid and solid  $\text{He}^4$  along the melting line over a finite temperature interval. A specific anomaly of the melting pressure consisting in a shallow temperature minimum is predicted at low temperatures, where both the liquid and solid phases are assumed to exhibit normal static thermal properties. The persistence of the anomalous equilibrium properties of liquid  $\text{He}^4$  on solidification is discussed qualitatively as suggesting a similar origin of these anomalies in both phases, such a situation having been shown previously to exist with respect to the thermal anomalies of liquid and solid  $\text{He}^3$ .

## Superconductivity

6995 THE ROLE OF SURFACE ENERGY IN THE PHENOMENON OF SUPERCONDUCTIVITY. V.L.Ginzburg. Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 994-8 (1958). In Russian.

A phenomenological theory of the energy of the surface between superconducting and normal phases of a metal is developed. It is shown how the maximum field in which the superconducting phase can exist (critical superheating field), the minimum field in which the normal phase can exist (critical supercooling field), and the dependence of penetration depth on magnetic field can be calculated. Some comparisons with experiment are made, and the need for more detailed experiments is emphasized. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 16, 34-8 (1958)].

D.J.Thouless

6996 THE THEORY OF THE SUPERCONDUCTIVE STATE. H.Fröhlich. Rep. Progr. Phys. (GB), Vol. 24, 1-23 (1961).

The development of the theory of the superconductive states is described in terms of simple physical ideas so far as this has been found possible. The isotope effect and gap are discussed, and the Meissner effect and gauge invariance are dealt with.

6997 ON SOME PROBLEMS OF THE THEORY OF SUPERCONDUCTIVITY. N.N.Bogolubov. Suppl. to Physica (Netherlands), Vol. 26, SI-SI6 (Dec. 26, 1960). International Conference on Many-Particle Problems, Utrecht, 1960 (see Abstr. 1707 of 1961).

It is shown how an asymptotically exact ground state for the reduced Hamiltonian in superconductivity theory can be found. An upper bound for the ground-state energy is found in the usual way, and the method for finding a lower bound is outlined; this involves introducing a small source term which violates particle conservation. The method leads to a formulation of the theory in which the number of particles is explicitly conserved. The average value of a product of operators can also be found exactly, and the asymptotic behaviour of correlation functions is studied. Some general features of superconductivity theory, not established rigorously, are then discussed. The idea of a "quasi-average" is developed; a hypothetical source of particles is introduced to remove a "hidden degeneracy", and the limit of infinite volume is taken before the source is switched off. The idea is also illustrated by considering ferromagnetism and crystal structure. A quasi-average need not vanish even if conservation laws suggest that it should. The principle is enunciated that hidden degeneracies must be removed before perturbation theory is applied. D.J.Thouless

6998 COMPRESSIBILITY, ZERO-POINT ENERGY, AND SPECIFIC HEAT IN SUPERCONDUCTORS. T.G.Daunt and J.L.Olsen. Phys. Rev. Letters (USA), Vol. 6, No. 6, 267-9 (March 15, 1961).

Thermodynamic arguments show that the compressibility of a superconductor is slightly temperature-dependent. It follows that the Debye temperature, and so the zero-point energy, will also be temperature-dependent, and this will give rise to an additional specific heat term. Calculation shows that this may account for the apparent change in lattice specific heat found by Keesom and Bryant (Abstr. 13489 of 1960).

R.G.Chambers

6999 EXPERIMENTS ON THE SUPERCONDUCTIVITY OF THE Nb-Sn SYSTEM AND OF THE MIXED CRYSTALS  $\text{Nb}_3\text{Sn}-\text{Ta}_3\text{Sn}$ . H.G.Jansen. Phys. (Germany), Vol. 162, No. 3, 275-89 (1961). In German. In the system Nb-Sn, the compound  $\text{Nb}_3\text{Sn}$  (with a superconducting temperature of 18°K) is obtained by sintering techniques even

with strong deviation from stoichiometric composition of the samples. A possible incorporation of the excess elements into the  $\text{Nb}_3\text{Sn}$  lattice is manifested only by very minute changes of the critical temperature. A small atomic percentage of Nb excess causes a maximum of the critical temperature. The critical temperature of mixed crystals of  $\text{Nb}_3\text{Sn}$  and  $\text{Ta}_3\text{Sn}$  changes almost linearly with composition. This system seems to have some interest concerning theoretical aspects.

7000 SUPERCONDUCTING TRANSITION TEMPERATURE OF HIGH-PURITY TANTALUM METAL. J.G.C.Milne. Phys. Rev. (USA), Vol. 122, No. 2, 387-8 (April 15, 1961).

Measurements gave a zero-field value of  $4.457^\circ \pm 0.003^\circ \text{K}$ . The ratio of room temperature resistivity  $\rho_{295}$  to the residual resistivity  $\rho_{4.2}$  gave a measure of the purity of the sample, a value of 250 being obtained. These results compare very well with those of Budnick (Abstr. 16952 of 1960). The value of  $(dH_c/dT)$  near the zero-field transition temperature was  $-358 \text{ Oe}/^\circ\text{K}$ . An approximate theoretical estimate, similar to that done by Pippard for tin [J. Phys. Chem. Solids (USA), Vol. 3, 175 (1957)], shows that small amounts of impurity as measured by the residual resistance ratio will give a decrease in transition temperature of about half that observed experimentally.

7001 PRESSURE EFFECT ON SUPERCONDUCTING LEAD. M.Garfinkel and D.E.Mapother. Phys. Rev. (USA), Vol. 122, No. 2, 459-68 (April 15, 1961).

Techniques are described for measuring the effect of hydrostatic pressure on the critical field,  $H_c$ , of superconducting Pb. Pressures up to 650 atm were applied using solid helium as the pressure fluid. Observations were made from about  $7^\circ$  to  $1^\circ \text{K}$ , and values of  $dH_c/dP$ ,  $dT_c/dP$ , and the temperature variation of  $(\partial H_c/\partial P)_T$  are reported. From these data the value of  $(1/\gamma^*)(d\gamma^*/dP)$  is deduced, where  $\gamma^*$  is the temperature coefficient per unit volume of the normal electronic specific heat. The observed data are accurately represented over the full range of measurement by the equation  $H_c(P,T) = H_c(P)f(t)$  where  $t = T/T_c$  and  $f(t)$  is independent of pressure. The "similarity principle" requirement,  $H_c(P)/T_c(P) = \text{const}$ , is shown to be invalid for Pb. The results provide the basis for a discussion of the pressure effects on the net interaction potential,  $V$ , of the Bardeen, Cooper, Schrieffer theory (Abstr. 1708 of 1958) and the density of electronic states near the Fermi surface.

SUPERCONDUCTING COMPUTER ELEMENTS. See Abstr. 6690

## ELECTRICITY ELECTRICAL MEASUREMENTS AND CIRCUITS

7002 THE HAMILTONIAN FORMALISM OF DAMPING IN A TUNED CIRCUIT. K.W.H.Stevens. Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 515-25 (Feb., 1961).

The idea behind this work is the supposition that it should be possible to introduce damping into the quantum-mechanical discussion of a harmonic oscillator without a detailed description of the damping mechanism. A study is therefore made of an LC circuit coupled to an artificial (or transmission) line, using a Hamiltonian formalism. The whole system is conservative but, for the transmission line case, the LC circuit behaves as if it is damped. The most probable form for the Hamiltonian does not exhibit the damping in an obvious way. It is shown that by a suitable change of variables the Hamiltonian can be split into two time-dependent commuting parts, one of which has the form

$$e^{-2\alpha t} \frac{P^2}{2C} + e^{-2\alpha t} \frac{Q^2}{2L}$$

which has been previously used in a study of two-level masers, and which does display the damping. The new operators  $Q$  and  $P$  are studied and it is shown that they are related to the charges and currents in the LC circuit, but with the noise components due to the resistive loss (the transmission line) omitted. They are thus perhaps more natural variables to use than the actual charges and currents which do contain noise components. The problem of coupling a spin system to the current in the inductance is studied and the transition is made to the analogous problem of a spin system interacting with

a damped mode of a cavity resonator. The analysis is compared with one given previously by Stevens and Josephson (Abstr. 1181 of 1960) and it is shown that the results previously obtained in a heuristic way are valid provided that noise fluctuations are negligible.

- 7003 A SENSITIVE ELECTROSTATIC METER WITH A BALANCED REED. Y.L.Yousef and S.A.Zaher. J. sci. Instrum. (GB), Vol. 38, No. 5, 214-17 (May, 1961).

A new electrostatic meter is described for measuring by a null method resistance, capacity, power loss and power factor over a considerable range of values at mains frequency. The action of the device depends on the vibrations which are set up in a thin aluminium reed initially at rest under the influence of two opposite alternating electrostatic forces. It is arranged that the quantity to be measured upsets the equilibrium in these forces, but balance may be restored to  $10^{-4}$  by the adjustment of a potentiometer and/or a resistance. The theory is discussed and typical examples of the various applications are given.

- 7004 MEASUREMENT OF ELECTRICAL RESISTIVITY OF BULK METALS. J.E.Zimmerman. Rev. sci. Instrum. (USA), Vol. 32, No. 4, 402-5 (April, 1961).

Describes a.c. induction methods in which the specimen is in bulk form, no direct contact to it being required. Theoretical expressions are given for a sphere and for an infinite circular cylinder in a uniform applied a.c. field, and an experimental method is described which is applicable to any shape or applied field configuration.

CAPACITOR TECHNIQUE FOR MEASURING THE VELOCITY OF A PLANE CONDUCTING SURFACE. See Abstr. 6815

- 7005 TRANSISTORIZED CURRENT REGULATOR FOR A 12 INCH VARIAN MAGNET. P.Jung. J. Phys. Radium (France), Vol. 21, Suppl. No. 3, 39A-42A (March, 1960). In French.

Power transistors are used to control the current of a Varian V 4012 magnet. The voltage applied to the transistors is limited by a servo-mechanism which acts upon a variable transformer at the input of the rectifier. A stabilization factor of  $1.5 \times 10^5$  has been achieved. A detailed description of the instrument is given.

- 7006 AUTOMATIC COMPENSATION FOR THERMAL E.M.F.s. AND GALVANOMETER ZERO DRIFT IN A FEEDBACK FLUXMETER. T.M.Palmer. J. sci. Instrum. (GB), Vol. 38, No. 5, 209 (May, 1961).

Slow drift of a feedback fluxmeter is prevented by resistive feedback in addition to the differentiating circuit. Before a measurement the resistive path is opened whilst maintaining the voltage for zero drift.

- 7007 ACTIVE FILTER ELEMENT AND ITS APPLICATION TO A FOURIER COMB. F.T.May and R.A.Dandl. Rev. sci. Instrum. (USA), Vol. 32, No. 4, 387-91 (April, 1961).

An active bandpass filter has been developed with the desirable feature of wide Q control over the range of frequencies extending to  $\sim 4$  kc/s. The Q has been made as high as 250 with good stability characteristics over this range. The flexibility of the filter was illustrated by the construction of a filter bank tuned to select Fourier components of a 50 c/s periodic wave in a typical noise environment and recombine them with no added relative phase shift and with equal gain to improve the signal-to-noise ratio.

THE HAMILTONIAN FORMALISM OF DAMPING IN A TUNED CIRCUIT. See Abstr. 7002

COMPUTER ELEMENTS. See Abstr. 6690

- 7008 THE APPLICATION OF THE XYZ RECORDER TO RADIATION STUDIED. L.Grodzins. Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 241-9.

Simple coincidences are displayed by means of two crystals x and y. The pulses from each crystal are stretched at their maxima and are applied to the X and Y deflectors of the c.r.t., the beam of which is intensified for a few  $\mu$ sec after the pulses have been stretched. For the detection of triple coincidences a third crystal z is used which controls the beam intensity. Photographs of coincidence spectra are given and the use of the method in analysing a decay process is described.

W.G.Stripp

- 7009 DECADE SCALER FOR COLLEGE LABORATORY USE. L.V.East and P.A.Roys. Amer. J. Phys., Vol. 29, No. 5, 307-9 (May, 1961).

A relatively simple and inexpensive scaler is described which uses two decade counter stages followed by a mechanical register. This instrument is designed for use in radiation counting experiments utilizing Geiger-Müller detectors. The scaler has an input sensitivity of 0.3 V for negative pulses. The input resolving time is approximately 250  $\mu$ sec, which is adequate for the use intended.

- 7010 SIGNAL TO NOISE RATIO AND RESOLVING TIME IN PULSE AMPLIFIER FOR NUCLEAR DETECTORS. F.T.Arecchi, G.Cavalleri, E.Gatti and V.Svelto. Energia nucleare (Italy), Vol. 7, No. 10, 691-6 (Oct., 1960).

Upper limits of signal-to-noise ratio is theoretically calculated for charge-measuring amplifiers as used in connection with radiation detectors, taking into account the additional constraint of a given resolving time.

- 7011 CONSTRUCTION OF A CHRONOTRON FOR MEASUREMENT OF FLIGHT TIME OF FAST NEUTRONS. J.Duclos. J. Phys. Radium (France), Vol. 21, Suppl. No. 3, 19A-23A (March, 1960). In French.

A chronotron using the storage circuits of a 100 channel amplitude analyser is described. A time expansion is obtained by an arrangement of 6BN6 valves. The width at half maximum of the prompt coincidences curve is  $7 \times 10^{-10}$  sec for  $\gamma$ - $\gamma$  coincidences from  $\text{Co}^{60}$  and  $2 \times 10^{-9}$  sec for n- $\alpha$  coincidences from the (d,t) reaction.

## ELECTROSTATICS . DIELECTRICS

(The study of solids through their dielectric properties is included under Solid-State Physics; similarly for Liquid State and Gaseous State)

- 7012 THEORY OF POLARIZATION AND ABSORPTION IN DIELECTRICS. AN INTRODUCTORY SURVEY.

G.Wyllie. Progress in dielectrics, Vol. 2 (see Abstr. 5413 of 1961) p.1-27. The topics discussed include energy in dielectrics, linear behaviour, simple and less-simple mechanical models, static mechanical general statistical theory, the crystalline state and mechanisms of dielectric loss. 68 refs. J.B.Bi

- 7013 ARTIFICIAL DIELECTRICS. J.Brown.

Progress in dielectrics, Vol. 2 (Abstr. 5413 of 1961) p. 193-225. Artificial dielectrics are lattices of conductors in a dielectric medium, mainly used at microwave frequencies. This review considers the different types of artificial dielectric; the calculation of the refractive index, permittivity and permeability by classical dielectric theory, by transmission-line theory, and by other methods; the behaviour at an interface between free space and an artificial dielectric; and the construction and applications of artificial dielectrics. J.B.Bi

- 7014 THEORIES OF DIELECTRIC POLARIZATION AND RELAXATION. R.H.Cole.

Progress in dielectrics. Vol. 3 (see Abstr. 5414 of 1961) p. 47-99. Reviews the extent to which current dielectric theory is able to account for the observed behaviour in molecular terms. Three sections deal with the cases of equilibrium in gases, liquids and solids respectively. Relaxation problems are then discussed in terms of Debye and other relaxation functions. The final three sections consider relaxation in gases, in liquids and solutions, and in solids. 131 refs. J.B.Bi

- 7015 NEW TECHNIQUE FOR MEASUREMENT OF MICRO WAVE DIELECTRIC CONSTANTS. E.F.Labuda and R.C.LeCraw.

Rev. sci. Instrum (USA), Vol. 32, No. 4, 391-2 (April, 1961). The technique overcomes several disadvantages of currently standard methods. Perturbation techniques are used with thin rod samples placed in a  $\text{TM}_{012}$  cylindrical cavity in such a manner that all undesirable effects of the ends of the rod are eliminated. A considerable increase in repeatability and ease of measurement is obtained.

CHARACTERISTIC CURVES OF A PYRAMID TYPE OF  
LECTRET. See Abstr. 6198

DIELECTRIC WAVEGUIDES AND AERIALS. See Abstr. 7151

## CURRENT ELECTRICITY ELECTROKINETICS

(The study of solids through their electrical conduction  
properties is included under Solid-State Physics)

7016 SPATIAL CORRELATIONS IN THE THERMAL  
FLUCTUATIONS OF ELECTRICAL QUANTITIES IN THE  
PRESENCE OF CONDUCTING SURFACES.

Morris with an additional Note by R.Fürth.  
Physica (Netherlands), Vol. 26, No. 9, 687-96, 696-7 (Sept., 1960).

Because of the thermal motion of its constituent elementary  
particles, an instantaneous measurement of charge in any small  
part of a conducting surface must be considered as a random variable.  
It is found that the statistics of these random variables can  
be described by a correlation function related to the Green's  
function for the surface. Potential fluctuations in the system may  
similarly be described by a correlation function which is the solution  
of Laplace's equation for a particular set of boundary conditions.  
Specific results for a spherical surface are given.

7017 CALCULATION OF EDDY CURRENTS BY MEANS OF  
ELECTRIC VECTOR POTENTIAL. M.P.Zlatev.  
Phys. Radium (France), Vol. 21, Suppl. No. 3, 16A-18A  
(March, 1960). In French.

Shows a relatively simple method for eddy current calculation,  
making use of the vector potential of an induced electric rotational  
field. This vector is determined by the equation

$$A = \frac{e}{4\pi} \oint_{\Gamma} \frac{dl'}{r}$$

where the integration extends over a closed unbranched inducing  
magnetic contour. The method is based on Ohm's law in differential  
form, by applying Stokes' theorem. The results obtained

$$i = -G \frac{d\Phi}{dt} \text{ and } G = \frac{\gamma}{4\pi} \int_{\Gamma} \oint_{\Gamma'} \frac{dl \cdot dl'}{r}$$

can be used for practical calculation of electrical induction  
apparatus.

NOISE IN ELECTRONIC DEVICES. See Abstr. 7088

7018 POTENTIALS IN A CONDUCTOR OF VARYING CROSS  
SECTION. R.Jaggi.

Phys. Rev. (USA), Vol. 122, No. 2, 448-9 (April 15, 1961).  
A Bernoulli voltage,  $V_B$ , proportional to the square of the  
current  $I$ , may be expected in a conductor of varying cross-section.  
Previous experiments to detect  $V_B$  are discussed. It is pointed out  
that in such experiments a Hall voltage,  $V_H \propto I^2$ , due to the  
magnetic field of the current  $I$  ("eigen-Hall effect", EHE), is super-  
posed on  $V_B$ . The ratio  $V_H/V_B$  is calculated. Experiments were  
performed on a bismuth sample of varying cross-section. The  
dependence of the measured voltages upon temperature and cross-  
sectional area shows that the EHE is dominant over the Bernoulli  
effect.

7019 ON A VARIATION PRINCIPLE FOR CALCULATING  
THE ELECTRICAL CONDUCTIVITY. H.Nakano.

Progr. theor. Phys. (Japan), Vol. 22, No. 3, 453-5 (Sept., 1959).  
A formulation is given of the author's method (Abstr. 8765  
(1956) for calculating the electrical conductivity, by means of a  
variational principle. The trial functions are related to the density  
matrix of the system, and the extremum value is a component of the  
electrical conductivity tensor. L.Pincherle

7020 A DIRECT THERMAL-TO-ELECTRIC ENERGY  
CONVERTER. S.Klein.

R. Acad. Sci. (France), Vol. 251, No. 22, 2492-4 (Nov. 28, 1960).  
French.

This note gives further results on a scheme previously des-  
cribed (Abstr. 19671 of 1960). A jet of gas, ionized in a flame, is  
passed through two consecutive metal tubes, insulated by a short

length of glass tubing. It is found that provided there is a tempera-  
ture gradient in the direction of motion, a significant p.d. is estab-  
lished between the two tubes. This gradient was measured under  
various load conditions by probes inserted in the glass-tube insul-  
ator. The qualitative results obtained are discussed. E.A.Ash

7021 APPARATUS REVIEW: THERMOELECTRIC  
GENERATOR. W.H.Michener.

Amer. J. Phys., Vol. 29, No. 4, 273 (April, 1961).

Tests were made of the performance of a commercially  
available thermoelectric generator intended for classroom  
demonstrations. The unit contained 150 series-connected thermo-  
couples made of constantan and nickel-molybdenum alloy, and it  
could supply about 0.4 W to a matched load when the junctions were  
heated by a gas flame. C.Hilsum

## IONIZATION

SENSITIVITY OF VG-1A IONIZATION GAUGE CALCULATED  
FROM THE PROBABILITY OF IONIZATION OF GASES. See  
See Abstr. 6914

THERMAL-ELECTRICAL ENERGY CONVERSION IN MOVING  
IONIZED GAS. See Abstr. 7020

7022 RUN-AWAYS IN NEUTRAL GAS.

G.Ecker and K.C.Müller.  
Z. Naturforsch. (Germany), Vol. 16a, No. 3, 246-52 (March, 1961).  
In German.

The motion of electrons as determined by the field acceleration  
and the elastic and inelastic collisions with the gas atoms, is cal-  
culated from the Boltzmann equation. The average velocity and the  
scattering ellipsoid are derived as a function of time. For particles  
starting from rest there exists always a critical electric field  $E_c$   
depending on pressure and temperature. Below this critical value,  
electrons approach the stationary drift process. Above the critical  
value, the electrons do not reach a stationary state, they "run away".  
For a finite initial velocity  $v_0$  and a field below the critical value  $E_c$   
the particles are either accelerated to drift, or decelerated to drift,  
or "run away", depending on the value  $v_0$ . From a calculation of the  
scattering parameters one finds for  $E > E_c$  a focusing effect in the  
velocity space which increases with field strength. Also the relaxa-  
tion time for the drift process and the stopping power for electron  
beams can be calculated. Applications to glow discharges are  
discussed.

7023 IONIZATION POTENTIALS OF MULTIPLY CHARGED  
KRYPTON, XENON, AND MERCURY.

F.H.Dorman and J.D.Morrison.  
J. chem. Phys. (USA), Vol. 34, No. 4, 1407-10 (April, 1961).

The determination of threshold potentials for multiple ionization  
processes is shown to depend on the threshold law assumed for these  
processes. Further support is obtained for the previously proposed  
n-th power rule for n-fold ionization by electron impact, and limits  
are set to the values of the thresholds for multiple ionization in the  
rare gases and mercury.

7024 IONIZATION PRODUCED BY ATOMIC COLLISIONS  
AT keV ENERGIES. III. J.B.Bulman and A.Russek.  
Phys. Rev. (USA), Vol. 122, No. 2, 506-11 (April 15, 1961).

For Pt II, see Abstr. 12399 of 1959. The electron evaporation  
model of the collision-ionization process that occurs when atoms  
collide at high energies is extended to include atoms with from two  
to eight electrons in the outer shell. Application of the model to  
data from collisions of  $N^+$  on A and  $Ne^+$  on A gives evidence for a  
resonant electron capture effect taking place in high-energy violent  
collisions which was heretofore masked by the multiple ionization  
consequent on such collisions.

7025 STRUCTURE IN THE IONIZATION NEAR THRESHOLD  
OF RARE GASES BY ELECTRON IMPACT.

S.N.Foner and B.H.Nall.  
Phys. Rev. (USA), Vol. 122, No. 2, 512-24 (April 15, 1961).

Ionization efficiency curves for xenon, krypton, and argon were  
studied with an electron energy analyser. The electron energy  
distribution was measured and the absolute voltage scale deter-  
mined in each experiment. The results of these studies (1) favour  
a linear threshold ionization law over a 1.127 power law, and  
(2) show that the data cannot be explained simply by ionization  
processes with onsets at the  $^2P_{3/2}$  and  $^2P_{1/2}$  ground states of the ion,  
but can be well fitted by a series of linear processes. The ioniza-

tion potentials obtained by extrapolating according to a linear threshold law agree with spectroscopic values to within 0.02 eV. New onsets in argon were observed at about 0.64 V and 1.27 V above threshold. The observed structures in the rare gases are not readily explained by auto-ionization and no alternative explanation is offered. The structures observed in these experiments are compared with the results obtained by other "high-resolution" techniques. This comparison is complicated by the disparity in the published data on onset energies, and by the even greater disagreement on the relative probabilities for the various ionization processes. An independent check on consistency of data was made by comparison with "low-resolution" data obtained on a conventional mass spectrometer. The present data are in excellent agreement with the lower resolution data, while some of the other "high-resolution" data are not.

**7026 MEASUREMENT OF TOWNSEND'S IONIZATION COEFFICIENTS AND ATTACHMENT COEFFICIENTS IN OXYGEN.** A.N. Prasad and J.D. Craggs.

Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 385-98 (Feb., 1961).

Pre-breakdown currents and breakdown potentials were measured in oxygen over a pressure range of 60-600 mm Hg and E/p range of 35 to 50 V cm<sup>-1</sup>(mm Hg)<sup>-1</sup>. From the semi-logarithmic plots of current against electrode separation, the Townsend ionization coefficient  $\alpha/p$ , and attachment coefficient  $\eta/p$  and a generalized secondary coefficient  $\gamma$  (where present) were evaluated employing the modified Townsend current growth equation. From the values of  $\alpha/p$  and  $\eta/p$  so obtained and from the earlier measurements, the mean cross-section for ionization and attachment were evaluated and by comparison with those obtained from low pressure (single collision) experiments, the electron attachment in O<sub>2</sub> under high-pressure swarm conditions was interpreted in terms of the dissociative attachment process. Lastly, from the measured values of  $\alpha/p$ ,  $\eta/p$  and  $\gamma$ , values of the breakdown gap  $d_B$  were evaluated for the E/p range 40-50, employing the modified Townsend breakdown criterion and by comparison with the measured values, the uniform field breakdown in O<sub>2</sub> at threshold was interpreted in terms of the Townsend build-up processes up to a pd of approximately 250 mm Hg cm.

**7027 MULTI-QUANTUM RECOMBINATION IN AN IONIZED GAS.** S.T. Belyaev and G.I. Budker.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 45-55.

Using the classical Boltzmann equation, the transition of an electron to the ground level of the atom owing to multiple collisions and emission of small quanta is considered. A method of simplifying the Boltzmann equation when collisions are infrequent is used.

**7228 BLANC'S LAW — ION MOBILITIES IN HELIUM-NEON MIXTURES.** M.A. Biondi and L.M. Chanin.

Phys. Rev. (USA), Vol. 122, No. 3, 843-7 (May 1, 1961).

The mobilities of ions of near thermal energies were measured in helium-neon mixtures using a drift velocity apparatus. These studies permit the investigation of ion motion in gases, e.g. He<sup>+</sup> in Ne, under conditions where the charge transfer interaction is negligible compared to polarization attraction and short-range repulsion between ion and atom. In addition, the measurements provide a test of Blanc's empirical law (1908),  $1/\mu = f_1/\mu_1 + f_2/\mu_2$ , which relates the mobility  $\mu$  in a binary mixture to the pure gas mobilities  $\mu_1$  and  $\mu_2$  and to the fractional gas concentrations  $f_1$  and  $f_2$ . A theoretical treatment developed by Holstein [Phys. Rev. (USA), Vol. 100, 1230(A) (1955)] is presented which shows that deviations from Blanc's law are limited to a few percent. The mobilities of He<sup>+</sup>, He<sub>2</sub><sup>+</sup> and Ne<sub>2</sub><sup>+</sup> ions are found to obey accurately Blanc's law. However, the "Ne<sup>+</sup>" ion curve deviates markedly from the law. These deviations are explained in terms of the formation of moderately stable (HeNe)<sup>+</sup> ions from Ne<sup>+</sup>. Finally, the observed mobilities of He<sub>2</sub><sup>+</sup> in Ne and Ne<sub>2</sub><sup>+</sup> in He are found to agree with the predictions of polarization theory.

**THE ELECTRICAL CONDUCTIVITY OF IONIZED AIR IN A SHOCK TUBE.** See Abstr. 6910-11

**7029 IONIZATION AND DISSOCIATION OF H<sub>2</sub>, N<sub>2</sub> AND CO IN CHARGE EXCHANGE COLLISIONS WITH POSITIVE IONS.** E. Gustafsson and E. Lindholm.

Ark. Fys. (Sweden), Vol. 18, Paper 13, 219-39 (1960).

A double mass spectrometer was constructed which permits the measurement of charge exchange cross-sections for collisions between molecules and ions with kinetic energies between 900 and 25 eV. Mass spectra of the collision products are obtained, H<sub>2</sub>, N<sub>2</sub>, and CO were bombarded with 15 different atomic ions and the cross-

sections for the production of H<sub>2</sub><sup>+</sup>, H<sup>+</sup>, N<sub>2</sub><sup>+</sup>, N<sup>+</sup>, CO<sup>+</sup>, C<sup>+</sup>, and O<sup>+</sup> were determined as a function of the ion kinetic energy. The processes in the collision chamber are discussed in terms of the known recombination energies of the atomic ions and the appearance potentials of the molecular fragments investigated.

**7030 STUDY OF REACTIONS PRODUCED BY MOLECULAR HYDROGEN IONS PASSING THROUGH A GAS.**

J. Guidini, R. Belna, G. Brifford and C. Manus.

C.R. Acad. Sci. (France), Vol. 251, No. 22, 2496-8 (Nov. 28, 1960).

In French.

A 10<sup>-15</sup> A, 10-60 keV beam of H<sub>2</sub><sup>+</sup> ions is passed through a reaction chamber, and the neutral and charged particle reaction products detected by scintillation counters. Preliminary values of two combined cross-sections for 45 keV in hydrogen gas are given. The angular spreads of the H<sub>1</sub><sup>0</sup> and H<sub>1</sub><sup>+</sup> reaction products were both estimated photographically to be about 0.8°, compared with about 0.1° for the H<sub>1</sub><sup>+</sup> incident beam.

R.S. Pearson

**7031 ELECTRON CAPTURE FROM He(1s<sup>2</sup>) BY PROTONS.** R.A. Mapleton.

Phys. Rev. (USA), Vol. 122, No. 2, 528-33 (April 15, 1961).

The two equivalent forms of Born's approximation, prior and post, are used to calculate the electron capture cross-section for protons incident on He(1s<sup>2</sup>). These cross-sections are calculated for capture into eleven different final states in the energy range 12.5 keV to 1 MeV. Although a rather crude wave-function,  $(Z^3/\pi a_0^3) \exp[-(Z/a_0)(r_1 + r_2)]$  ( $Z = 1.6875$ ), is used for He, the prior and post total capture cross-sections do not differ by more than 20% over the energy range investigated. Estimates of the sum of the cross-sections for capture into all s states of the hydrogen atom for the two residual ions, He<sup>+</sup>(1s) and He<sup>+</sup>(2s), are obtained from an adaption of the s-state sum rule as given by Jackson and Schiff (Abstr. 2515 of 1953). As in this work of Jackson and Schiff, it is found that the s states provide the major contribution to the total capture cross-section. The calculated cross-sections agree fairly well with the experimental values. The cross-sections for capture into the state He<sup>+</sup>(1s) + H(1s), is roughly 2.5 times larger than the values obtained by Bransden, Dalgarno and King (Abstr. 1951 of 1955).

## ELECTRIC DISCHARGES

**7032 HIGH CURRENT GAS DISCHARGES.** A.A. Ware.

Rep. Progr. Phys. (GB), Vol. 24, 25-64 (1961).

In this review high current discharges are taken to be those discharges whose self-magnetic fields play an important role in their behaviour. Such discharges have been studied mainly in connection with the quest for controlled thermonuclear reactions. Of the many possible configurations for the discharge tube and the electromagnetic fields, the pinch discharges in straight or toroidal tubes have received the most attention and accordingly, a major part of this review is devoted to these discharges. Other configurations are reviewed in a separate section. Following an historical and introductory review of the subject, a set of appropriate plasma equations is presented, and the common approximations and physical concepts associated with the theory are discussed. The properties of the pinch discharge are considered under the headings — discharge initiation and contraction, equilibrium, magnetohydrodynamic stability, particle heating and energy loss, and nuclear reactions — and in many cases it is necessary to subdivide the sections according to whether the rate of rise of current is high or low.

**7033 SOME PROPERTIES OF HIGH-FREQUENCY CORONA RADIATION DISCHARGE.**

N.B. Bogdanova and V.I. Popkov.

Dokl. Akad. Nauk SSSR, Vol. 134, No. 6, 1331-3 (Oct. 21, 1960).

In Russian.

For abstract, see Abstr. 4575 of 1961. [English translation in Soviet Physics—Doklady (USA), Vol. 5, No. 5, 1090-3 (March-April, 1961)].

**7034 TRANSITIONS BETWEEN THE GLOW AND ARC REGIMES.** Y. Leycuras.

C.R. Acad. Sci. (France), Vol. 252, No. 7, 1005-7 (Feb. 13, 1961).

French.

Reports a study of the transition between glow and arc discharges at pressures below atmospheric with direct and alternating

currents. Consideration is given particularly to the effect of the circuit parameters on the transitions. High-frequency oscillations exist in the glow-arc regime. An equivalent current is given in terms of the inductance and capacitance of the external circuit and the impedance of the discharge. Evidence is discussed whereby the oscillations in the glow regime are caused by current discharge into the electrode gap and consequent relaxation phenomena.

H. Edels

**CATHODIC ETCHING IN A PENNING COLD CATHODE DISCHARGE.** See Abstr. 6493

**ELECTRIC AND MAGNETIC PROPERTIES OF PLASMA OF LOW-POWER PULSE DISCHARGES.** See Abstr. 7079

**7035 THE EFFECT OF THE MAGNETIC FIELD SHAPE ON A RING GAS DISCHARGE.** Yu. F. Nasedkin and E. I. Pavlov. "Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 254-79.

The behaviour of a gas current ring in a betatron field is studied, and the distribution of current density over the cross-section of the chamber is investigated. The effect of the magnetic field shape on the behaviour of the current ring is determined. At low gas pressures in the chamber, X-radiation is recorded. Deuterium and argon were used.

**7036 INVESTIGATION OF A POWERFUL RING GAS DISCHARGE WHEN THERE IS AN EQUILIBRIUM ORBIT.** Yu. F. Nasedkin and S. M. Osovets.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 213-30.

A ring discharge in a variable magnetic field is considered, the field having a special configuration which ensures the existence of a stable equilibrium current orbit. The current distribution over the volume of the vacuum chamber is investigated. The maximum energy of motion of the ring towards the centre of the chamber after breaking away from the orbit is estimated to be  $\sim 1500$  eV. The residual magnetic flux and resistance of the gas ring are estimated.

**7037 THE INVESTIGATION OF A POWERFUL ELECTRIC DISCHARGE IN DEUTERIUM.**

V. S. Komel'kov, T. I. Morozova and U. V. Skvortsov.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 244-59.

Oscillograms of I and V are given for a discharge in deuterium with  $C = 24-36 \mu\text{F}$ ,  $I_{\text{max}} = 550$  kA, a tube diameter of 630 mm, a pressure range  $p_0 = 0.0025-1$  mm Hg, and an initial voltage  $V = 40-100$  kV. Several singularities were observed in the current. The integral neutron flux was recorded, as a function of  $C$ ,  $V_0$  and  $p_0$ . The times of appearance and the duration of the neutron pulses were determined. The X-radiation accompanying the neutrons was investigated.

**7038 MEASUREMENT OF PLASMA CONDUCTIVITY DURING A PROLONGED PASSAGE OF CURRENT.** V. D. Kirillov.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 260-73.

The procedure and experimental results are described of an investigation of powerful (currents up to 95 kA), low-frequency ( $f = 270$  c/s) discharges in deuterium. Voltage oscillograms are given for discharges both in the presence of a longitudinal, magnetic field and in its absence; curves of the change in interelectrode resistance as a function of time, very-high-speed photographs for condenser voltages  $U_C = 6$  kV, and curves of the distribution of potential along the axis of the discharge tube are also given.

**7039 THE STUDY OF A GAS DISCHARGE IN A SIMPLY CONNECTED REGION.**

S. M. Osovets, Yu. F. Petrov and N. I. Shchedrin.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 326-60.

Results are given of a study of a gas discharge in a simply connected region produced by the application of an alternating magnetic field. It is shown that for such a discharge a plasma current ring is formed, which subsequently contracts towards the centre of the discharge vessel. Theoretical studies have shown that, by choosing a suitable shape of magnetic field, it should be possible to obtain a region where a plasma ring can exist in a state of equilibrium. In experiments with an apparatus provided with a magnetic field satisfying these conditions, hard X-radiation (having energies of some hundreds of keV) were observed showing that, in principle, electron acceleration of the betatron type can be realized using such devices although no preliminary electron injector is employed. During the first quarter cycle of the primary current, the plasma current in the gas discharge ring builds up to a value of 80 kA. However, the plasma ring does not exist in a stable orbit for very long. This instability is explained by the fact that the plasma ring has considerable ohmic resistance — a factor which was neglected in

the theoretical analysis. From the results of the experiments described, however, one is able to see what improvements are required in the further development of this type of apparatus.

**7040 STUDY OF A RING DISCHARGE IN A TRANSVERSE MAGNETIC FIELD.** Yu. F. Nasedkin.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 361-82.

The apparatus described was constructed with the aim of reducing the effects due to the resistance of the plasma ring when exciting a gas discharge of the kind considered in the preceding abstract. This apparatus provides a magnetic field of the required form, has a low inductance ( $L = 0.15 \mu\text{H}$ ) and a large coupling coefficient ( $K = 0.35$ ). The secondary current distribution through the volume of the discharge vessel was studied. During the first half cycle, it was found that the secondary current breaks away from the walls and occupies the region of the calculated stable orbit. When the primary current reaches approximately its maximum value, the secondary current collapses and the entire discharge moves away from this orbit towards the centre. During the second and subsequent half cycles, the discharge fills the whole volume of the discharge vessel.

**7041 THEORY FOR THE CATHODE MECHANISM IN METAL VAPOR ARCS.** T. H. Lee and A. Greenwood. J. appl. Phys. (USA), Vol. 32, No. 5, 916-23 (May, 1961).

It is shown that in the cathode drop region of a metal vapour arc, there are four equations and two limiting conditions relating five dependent variables. The dependent variables treated are temperature of the cathode spot, electric field at the cathode, total current density, current density carried by electrons, and the radius of the spot. When these equations are combined, a current level is found below which no solution exists. It is proposed that this current corresponds to the point at which a vacuum arc extinguishes in an alternating-current circuit. Experimental measurements of the current level at which this event occurs were made, and the results are compared with the theoretical calculations.

**7042 ELECTRICAL BREAKDOWN IN HYDROGEN AT LOW PRESSURES.** A. L. Ward and E. Jones.

Phys. Rev. (USA), Vol. 122, No. 2, 376-80 (April 15, 1961).

Experimental and theoretical determinations of the static voltage-current characteristics, extending from the region of the Townsend (self-maintained) discharge to the normal glow discharge, were carried out in hydrogen at low pressures (7-25 mm Hg). The calculations, made on an electronic computer, were based on the distortion of the electric field by space charge, and used the experimentally determined variation of both the primary and secondary Townsend ionization coefficients on the ratio of the field to pressure. Good agreement is obtained between the measured and calculated breakdown and glow voltages, and both the experimental and theoretical curves of the characteristic are of similar shape.

**BREAKDOWN OF  $\text{O}_2$  GAS.** See Abstr. 7026

**7043 INVESTIGATION OF PRESSURES IN A POWERFUL PULSED GAS DISCHARGE, USING A PIEZOELECTRIC MEASURING DEVICE.** N. V. Filippov.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 280-300.

The design of a piezoelectric instrument for measuring pressures in a pulsed discharge, and a method of using it in a cylindrical discharge chamber at currents of 300 to 500 kA, are described. Results are given of investigations of the pressure near the centre of the chamber in a deuterium discharge from a condenser bank of capacity  $62 \mu\text{F}$ . A new method is described for the direct calibration of the instrument in the gas discharge under investigation, using an inertia device with a diaphragm.

## PLASMA

(See also Magnetohydrodynamics)

**7044 PROCESSES ASSOCIATED WITH RAPID CURRENT RISE IN A PLASMA COLUMN.**

S. I. Braginsky and A. B. Migdal.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 28-38.

Examines briefly the main features of a high-current pulsed discharge: ionization; skin effect; motion of the ions towards the axis and the entrainment of neutral gas by them; the contraction of the plasma column, taking into account the increase in mass of the moving material; the temperatures of ions and of atoms.

7045 THE MAGNETIC FLUX IN A CONTRACTING CYLINDER.  
L.A.Artsimovich.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 135-52.

Considers the processes occurring in a uniformly contracting conducting cylinder placed in a magnetic field. Formulae giving the change of the cylinder radius as a function of time are derived for several cases. The interpretation of the experimental data and the possibility of determining the conductivity of the cylinder are discussed.

7046 ON STABILITY OF A PLASMA CYLINDER IN AN  
EXTERNAL MAGNETIC FIELD. T.F.Volkov.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 216-22.

Investigates the stability against ribbon-type perturbations of a plasma cylinder, carrying a current, in an external magnetic field directed along the axis. It is assumed that the current is distributed equally over the cross-section. It is shown that for a sufficiently large magnetic field, perturbations of the type considered are stable.

7047 A PLASMA RING IN AN ELECTROMAGNETIC FIELD.  
S.M.Osovets.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 322-5.

The basic principles of the theory of an electrodeless gas discharge having a definite configuration are examined. Conditions can be realized in this type of discharge which are to some extent analogous to the conditions existing in a betatron accelerator. The point at which acceleration of the electrons becomes possible in a betatron corresponds to the point at which plasma heating begins in a gas discharge of the kind considered here.

7048 [SIMPLIFIED] BOLTZMANN'S EQUATION FOR AN  
ELECTRON GAS IN WHICH COLLISIONS ARE  
INFREQUENT. G.I.Bubker and S.T.Beliaev.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 431-57.

The corresponding equations for a relativistic electron gas, employed in the study of the steady state of a stabilized electron beam, are also derived.

7049 SOME PROBLEMS OF THE SPATIAL STABILITY OF A  
RING CURRENT IN A PLASMA. G.I.Budker.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 34-44.

The stability is considered only with respect to slow changes, during which the equilibrium values of temperature and density are reached. Rapid changes and those occurring in times determined by inertia are not considered.

7050 THE [APPROXIMATE] BOLTZMANN EQUATION FOR  
RAREFIED [IONIZED] GASES IN STRONG FIELDS.  
S.T.Belyaev.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 56-76.

A method is demonstrated for obtaining this equation. The small parameter in this approximation is the ratio of the period of characteristic oscillations of the particles in the external field to the mean free time. The approximate equation has the form of a Fokker-Planck equation with a reduced number of variables.

7051 KINETICS OF AN IONIZED GAS IN A STRONG  
MAGNETIC FIELD. S.T.Belyaev.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 77-101.

An ionized gas in a strong magnetic field is regarded as an assembly of Larmor circles. The Boltzmann equation is derived for the distribution function of these circles. Its solution in the hydrodynamical approximation is discussed. The electron-ion diffusion coefficient in a uniform magnetic field is calculated. The fluxes in a non-uniform field are determined without allowance for collisions.

7052 RADIATIVE HEAT TRANSFER FROM A DENSE HIGH-  
TEMPERATURE PLASMA.  
V.V.Babikov and V.I.Kogan.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 102-15.

The heat transfer from a layer of plasma by bremsstrahlung, for any opacity, is calculated in connection with the problem of heating dense or condensed media. The transition from "transparent" to black radiation is discussed.

7053 RECOMBINATION RADIATION FROM A HYDROGEN  
PLASMA. V.I.Kogan.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 116-21.

The total intensity of recombination radiation from a rarefied hydrogen plasma is calculated as a function of the electron temperature, account being taken of recombination to excited levels. This quantity is compared with the intensity of bremsstrahlung.

7054 ELECTROMAGNETIC WAVES IN A RELATIVISTIC  
PLASMA IN A MAGNETIC FIELD. B.A.Trubnikov.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 122-32.

The relativistic dielectric permeability tensor  $\epsilon_{\alpha\beta}(k, \omega)$  is derived for a plasma in a uniform magnetic field. The thermal motion of the electrons is described by a (relativistic) Maxwellian distribution, and their collisions are supposed infrequent. By means of the dispersion equation the propagation of waves of the form  $\sim \exp i(k \cdot r - \omega t)$  is investigated. The emissive power of the medium and absorption coefficient for ordinary and extraordinary waves are calculated for frequencies  $\omega \gg |e\hbar/mc|$ .

7055 THE ELECTRON DISTRIBUTION FUNCTION IN A  
PLASMA IN A MAGNETIC FIELD. V.S.Kudryavtsev.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 133-40.

The electron distribution function in a two-temperature plasma is calculated for the case where the electrons receive energy by collisions with high-temperature ions and radiate it in their motion in the magnetic field. A stationary process is considered and the plasma is supposed completely transparent.

7056 MAGNETIC RADIATION FROM A PLASMA LAYER.  
B.A.Trubnikov and A.E.Bazhanova.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 141-74.

The magnetic bremsstrahlung from a plane layer of plasma in a magnetic field parallel to it is computed. The electron energies considered are just relativistic. The calculations are done for two forms of the electron energy distribution: a Maxwellian and a cutoff Maxwellian. It is shown that the radiation is trapped to the extent necessary for a self-sustaining thermonuclear D-D reaction only when the dimensions of the layer are considerable, lying at the limit of achievability.

7057 THE DECAY OF AN ARBITRARY DISCONTINUITY IN  
CONTINUOUS MEDIUM. T.F.Volkov.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 175-80.

A particular case of the decay of an arbitrary discontinuity in continuous medium is discussed in order to estimate the temperatures which can be obtained by the collision of dense beams of particles with one another or with a solid target. Some brief considerations on the possible effect of a magnetic field are also given.

7058 HIGH-FREQUENCY HEATING OF A PLASMA.  
L.I.Rudakov and R.Z.Sagdeev.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 181-92.

A method of heating plasma ions is considered, based on the utilization of cyclotron resonance. When the fields in the plasma due to the motion of ions and electrons are allowed for, the motion of the particles may be considerably modified, and the heating mechanism may no longer operate. To find the conditions under which ions may be accelerated, the problem of particle motion in an external field is considered, without allowance for the self-consistent field of the plasma itself. The effect of this field is analysed, using the hydrodynamical approximation.

7059 THE THEORY OF RAPID PROCESSES.  
S.M.Osovets.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 193-212.

Calculations are given for the rapid compression of a plasma column, taking into account the varying inductance of the circuit. The basic relations for the temperature of the compressed column and the compression time are derived. The conditions for separation of the plasma from the walls of the vessel are considered, and the mean temperature of the gas at the moment of separation is calculated.

7060 A PLASMA RING WITH A RESISTANCE.  
S.M.Osovets and N.I.Shchedrin.

"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 231-53.

A theoretical discussion is given of the conditions of equilibrium in the process of contraction of a plasma ring of finite conductivity. It is shown that, if the ring is to contract into a ball, the residual magnetic flux must be balanced by some field constant in time. Results of experiments with a compensating field are given, con-

firming the theoretical conclusions. The conditions under which the residual flux is completely balanced and the ring contracts to a ball are derived.

**7061 THE BEHAVIOUR OF FAST ELECTRONS IN THE ELECTRON MODEL OF A TRAP WITH MAGNETIC TOPPERS [MIRRORS].**

I.M. Antropov, V.A. Belyaev and M.K. Romanovskii.

Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 301-11.

Preliminary results are given of an investigation of the electron model of a magnetic trap with an axially symmetrical magnetic field which is stronger at the ends.

**7062 A QUASI-HYDRODYNAMIC DESCRIPTION OF A RAREFIED PLASMA IN A MAGNETIC FIELD.**

L.I. Rudakov and R.Z. Sagdeev.

Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 321-31.

The Boltzmann equation describing the motion, averaged over the Larmor revolution, of ions in a plasma in a magnetic field, in the absence of collisions, is generalized to the non-static case. The set of equations for the lower moments of the electron and ion distribution functions is similar to the equations of two-fluid hydrodynamics. Although the mean free path is formally infinite, it is replaced by the Larmor radius of the ion or electron. Using the equations obtained, the wave solutions corresponding to magnetohydrodynamic and acoustic oscillations are examined. When the pressure tensor is sufficiently anisotropic, instability arises and the plasma ceases to be homogeneous.

**7063 SOME PROPERTIES OF A PLASMA WITH AN ANISOTROPIC ION VELOCITY DISTRIBUTION IN A MAGNETIC FIELD. A.A. Vedenov and R.Z. Sagdeev.**

Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 332-9.

The possibility of instability of a plasma in a magnetic field owing to anisotropy of the ion velocity distribution is considered.

**7064 MAGNETIC TRAPS WITH A "CORRUGATED" FIELD. B.B. Kadomtsev.**

Plasma physics", Vol. III (see Abstr. 5493 of 1961) p. 340-55.

The motion of particles in magnetic traps in the absence of electric fields and currents in the plasma is discussed in the drift approximation. The method of investigation consists in averaging the equations of motion over the fast motion of the particles along the lines of force. It is shown that by "corrugating" the magnetic field the toroidal drift of the particles can be almost balanced. Two specific types of trap with corrugated field are considered.

**7065 STABILISATION OF A PLASMA BY THE USE OF GUARD CONDUCTORS.**

S.I. Braginskii and B.B. Kadomtsev.

Plasma physics", Vol. III (see Abstr. 5493 of 1961) p. 356-85.

A method is proposed for stabilizing the boundary of a plasma, whose pressure is balanced by a magnetic field. Stability is achieved by means of metallic guard conductors. These form a network on the plasma boundary, and carry part of the magnetic field pressure. This excess pressure prevents the plasma from passing outside the network. Such a system is shown to be stable for small oscillations. The shape of the plasma boundary near the network lines is considered.

**7066 A PLASMA IN A "MAGNETIC GRID". O.B. Firsov.**

Plasma physics", Vol. III (see Abstr. 5493 of 1961) p. 386-94.

The flow of an electron-ion plasma along lines of magnetic force surrounded by a constant magnetic field is considered. The magnetic field configuration is such that there is no field inside the plasma. The prospects of using such a system in constructing a thermonuclear reactor are assessed.

**7067 A STATIONARY PLASMA DENSITY DISTRIBUTION IN AN ELECTROMAGNETIC FIELD. T.F. Volkov.**

Plasma physics", Vol. III (see Abstr. 5493 of 1961) p. 395-405.

Using the hydrodynamical approximation, the problem of the stationary self-consistent density distribution of a plasma in the field of an electromagnetic standing wave is solved. It is shown that, in this approximation, there is no exact solution for which the plasma density is zero in some region of space. The effect of the magnetic field and of the walls bounding the plasma is also considered.

**MICROWAVE PROPAGATION THROUGH A MAGNETOPLASMA. (see Abstr. 7156)**

**7068 THE CALCULATION OF ENERGY DISTRIBUTION OF RELATIVISTIC ELECTRONS FROM THEIR SYNCHROTRON RADIATION. APPLICATION TO THE CRAB NEBULA.**

J. Jäger and G. Wallis.

Beitr. Plasma Physik (Germany), Vol. 1, No. 1, 44-63 (1960-61). In German.

**7069 WAVE INTERACTION IN PLASMA INHOMOGENEITIES. L. Wetzel.**

J. appl. Phys. (USA), Vol. 32, No. 2, 327-8 (Feb., 1961).

The wave interactions in an inhomogeneous plasma in an applied alternating electric field are discussed, using the phenomenological equations of motion and continuity. It was found that the local first-order combination currents generated in non-uniform regions may be large or small compared to the second-order currents generated in a uniform region, depending upon the relative size of the gradient of the density to the density itself, and the polarization of the primary field with respect to this gradient.

M. Hasan

**7070 ION RESONANCE IN A MULTICOMPONENT PLASMA. S.J. Buchsbaum.**

Phys. Rev. Letters (USA), Vol. 5, No. 11, 495-7 (Dec. 1, 1960).

Theory indicates that in a multicomponent cold plasma in an axial magnetic field at low plasma densities, resonances should occur at the various ion cyclotron frequencies. As the density is raised, interaction sets in between the various components and the resonances tend to the ion-ion hybrid frequencies. An experiment on the positive column of an arc discharge in helium with small hydrogen impurity confirmed the theory at low densities. As the density was raised, a shift to the hybrid frequencies was observed over a density change of two orders of magnitude. The existence of density gradients in the plasma may account for larger shifts than expected and anomalous behaviour of the line-widths.

J.W. Sturgess

**7071 CYCLOTRON INSTABILITY IN A PLASMA. A.B. Kitsenko and K.N. Stepanov.**

Zh. tekh. Fiz. (USSR), Vol. 31, No. 2, 176-9 (Feb., 1961). In Russian.

It is shown that an unbounded plasma with an anisotropic ion velocity distribution can be unstable against perturbations of wavelengths comparable with the ion Larmor radius and frequencies close to the ion gyrofrequency and its multiples. [English translation in: Soviet Physics—Technical Physics (USA)].

O. Penrose

**7072 DESCRIPTION OF AN ELECTRON-ION PLASMA. L. Ya. Kobelev.**

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 4, 754-6 (1958). In Russian.

Schwinger's method is used to derive equations for the Green's functions of an electron-ion plasma. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 4, 169-71 (1958)].

J. Goldstone

**7073 SOLUTION FOR THE TWO-ELECTRON CORRELATION FUNCTION IN A PLASMA. B.D. Fried and H.W. Wyld, Jr.**

Phys. Rev. (USA), Vol. 122, No. 1, 1-8 (April 1, 1961).

The two-electron correlation function,  $g$ , (responsible for "collisional" corrections to the correlationless (or Vlasov) description of a plasma, is investigated. It is shown that an exact solution of the integral equation for  $g$  can be found for a fairly wide class of spatially homogeneous, one-electron distribution functions,  $f$  (the ion dynamics being neglected). This is carried out in detail for the simplest member of the class (the resonance shape), and the Landau damping of  $g$  to its asymptotic ( $t \rightarrow \infty$ ) form is exhibited explicitly. It is shown that correlations between particles separated by more than the Debye length are damped in a time which exceeds the period of plasma oscillations,  $\omega_p^{-1}$ , and that these make an appreciable contribution to the "collisional" rate of change of  $f$ . It is concluded that for rapidly varying  $f$  (as in problems involving plasma oscillations) conventional treatments of the "collision" term should be replaced by a self-consistent solution of the coupled equations for  $f$  and  $g$ .

**7074 EXPERIMENTAL STUDY OF THE DIAMAGNETISM OF GASEOUS PLASMAS WITH ELECTRON AND NUCLEAR SPIN RESONANCE TECHNIQUES. T.C. Marshall and L. Goldstein.**

Phys. Rev. (USA), Vol. 122, No. 2, 367-76 (April 15, 1961).

It has been possible to observe the occurrence of diamagnetism in active discharges by measuring shifts in spin absorption resonance frequencies of foreign substances located near the plasma.

Narrow spin electronic resonances in DPPH were used to show that the magnetization of a gaseous discharge in low-pressure mercury vapour increases linearly with applied magnetic field up to about 40 G, where maximization occurs. Observation of the phase change in the Larmor precession of protons in a strong homogeneous field showed that the diamagnetism in a modified Penning ionization gauge discharge increased linearly with power input and decreased approximately as  $1/H$ . Irradiation of the plasma with high-power microwaves with frequency near the free-electron gyrofrequency resulted in an increase of diamagnetism of the discharge. The discharge magnetic moment ranged from  $-0.001$  to  $-0.32$  erg/cm<sup>3</sup> gauss, depending on experimental conditions. The sensitivity of the nuclear resonance technique is one part in  $10^6$ , and it permits observation of diamagnetism to be deferred until the discharge is over. The theory of plasma diamagnetism is summarized.

7075 INCOHERENT MICROWAVE RADIATION FROM A PLASMA IN A MAGNETIC FIELD.

J.L.Hirshfield and S.C.Brown.

Phys. Rev. (USA), Vol. 122, No. 3, 719-25 (May 1, 1961).

The microwave emission from a plasma in a magnetic field is calculated theoretically using Kirchhoff's radiation law for cases when characteristic waves do not couple within the plasma. Experimental observations of radiation temperatures and cyclotron radiation line breadth and shape are cited to illustrate applications of the theory to experiment.

7076 EXACT RELATIVISTIC FOKKER-PLANCK COEFFICIENTS FOR A PLASMA. A.Simon.

Phys. of Fluids (USA), Vol. 4, No. 5, 586-99 (May, 1961).

A plasma is considered which, in zero order, is static, spatially uniform, and infinite in extent and with no external electric or magnetic fields. Exact relativistic Fokker-Planck coefficients are obtained by a solution of the first-order coupled integral equations for the particle and oscillator pair correlation functions. The solution is by a generalization of the method of Lenard and Balescu. The resulting coefficients have contributions from both Coulomb interactions and from interactions via transverse electromagnetic fields.

7077 DIFFUSION OF PLASMA ACROSS A MAGNETIC FIELD. J.B.Taylor.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 262-3 (March 15, 1961).

The application of fluctuation theory (Abstr. 17011 of 1960) to transverse diffusion in a plasma gives an expression which covers both classical and Bohm diffusion. The latter corresponds to the maximum value the diffusion can attain for ions of a specific mean energy.

J.W.Sturgess

7078 A NECESSARY STABILITY CRITERION FOR A TOROIDAL HYDROMAGNETIC SYSTEM WITH SCALAR PRESSURE. C.Mercier.

C.R. Acad. Sci. (France), Vol. 252, No. 11, 1577-8 (March 13, 1961). In French.

Solutions of the hydromagnetic equations exist for which surfaces of constant pressure are closed toroidal surfaces on which the magnetic field and current density vectors lie. By applying the minimum energy principle to disturbances in the neighbourhood of the surfaces, a stability criterion is obtained which involves integrals over the surface of functions of the magnetic field, pressure and their gradients, which is given explicitly for surfaces having large ( $>> 2\pi$ ) rotational transform angles.

R.S.Pease

7079 ELECTRIC AND MAGNETIC PROPERTIES OF PLASMA OF LOW-POWER PULSE DISCHARGES. B.Piekara.

Bull. Acad. Polon. Sci. Ser. Sci. math. astron. phys. (Poland), Vol. 7, No. 12, 741-4 (1959).

An argon plasma at pressures between 3 and 15 cm Hg was investigated. The plasma resistance was low, indicating high ionization. The peak potential increased linearly between electrodes indicating even electron and ion distributions. In a transverse magnetic field the peak intensity of light output increased with the field, whereas in a longitudinal field it decreased. This suggests that a transverse field may cause the plasma temperature to increase. Contact with walls may be avoided using a suitably shaped field.

J.W.Sturgess

7080 ENERGY BALANCE AND CONFINEMENT OF A MAGNETIZED PLASMA. B.Lehnert.

Ark. Fys. (Sweden), Vol. 18, Paper 15, 251-71 (1960).

Under laboratory conditions particle losses from a magnetized plasma will produce a neutral particle flux reentering from the surrounding vessel walls into the plasma region. Even at very high temperatures, where the plasma is almost fully ionized, this

gives rise to interactions between charged and neutral particles which cannot always be neglected. Three types of interactions are discussed; ionization, charge exchange and elastic collisions with neutrals. The conservation laws of mass, charge, momentum and energy are reconsidered for a two-fluid system with ionization, charge exchange and elastic scattering of neutral particles taken into account. It is found not to be necessary to derive the energy equation in terms of the joint action of electromagnetic and mechanical changes of state. It has earlier been concluded by Bonneville and Lehnert (Abstr. 5315 of 1960) from the motion of a single particle that a very strong confinement can be obtained in a rotating plasma situated in the magnetic field of a current loop. These results are verified in a macroscopic theory including the energy balance of stationary motion. It is found that the main part of the heating of the plasma and the scattering of ions are not provided by coulomb collisions, but by collisions with reentering neutral particles. Two special cases are treated in detail, one with vanishing heat conductivity and one with infinite heat conductivity in the direction along the magnetic field. For the latter, which is more likely to occur in high temperature plasma, the energy loss by escaping particles is deduced. The theory predicts that this loss should be several orders of magnitude less in the current loop configuration than in earlier described homopolar machines. Finally, some comments are given on the non-existence of interchange instabilities in systems with volume currents.

7081 PLASMA INJECTION INTO A VACUUM MAGNETIC FIELD. F.R.Scott and H.G.Voorhies.

Phys. of Fluids (USA), Vol. 4, No. 5, 600-6 (May, 1961).

Experimental measurements were made on the axial injection of dense, highly directed plasmas of deuterium, hydrogen, and helium into a cusp magnetic field. Magnetic probe measurements show that during injection a diamagnetic region forms over a radius which varies inversely with the axial field strength for each type of plasma. Axial velocities of the dense plasma are measured with a movable loop-permanent magnet assembly. For deuterium the mean axial velocity was  $v_0 = 8.7 \pm 0.5 \times 10^6$  cm/sec, for helium  $v_0 = 1.08 \pm 0.5 \times 10^7$  cm/sec and for hydrogen  $1.4 \pm 0.1 \times 10^7$  cm/sec. Optical emission line shapes for helium show a Doppler width equal to  $118 \pm 11$  eV in the peak axial field region during injection. Deuterium emission lines gave both ion kinetic temperature and ion densities after injection which indicate reasonable containment with high  $\beta$ . A simple hydrodynamic model of a supersonic diffusion compares favourably with the experimental observations during injection for both deuterium and helium.

7082 EXPERIMENTS WITH PULSED MAGNETIC CUSPS. J.P.H.Watteau.

Phys. of Fluids (USA), Vol. 4, No. 5, 607-10 (May, 1961).

Experiments with a simple pulsed magnetic field in cusped geometry are described. The plasma is generated inside the containment region rather than injected from an external source. It was found that creation of the plasma by a linear pinch discharge is most successful. Only qualitative studies have been carried out so far, using time-resolved visual observation of the plasma. Well defined plasma bodies located in the central region between the cusps were photographed. In order to make them clearly visible, a few percent of argon was added to the hydrogen.

7083 INDUCTION-COUPLED PLASMA TORCH. T.B.Reed.

J. appl. Phys. (USA), Vol. 32, No. 5, 821-4 (May, 1961).

A new method of generating a stable plasma at atmospheric pressure using inductive coupling at a frequency of several Mc/s is described. Methods of starting and operating this plasma in argon and mixtures of argon with helium, hydrogen, oxygen, and air are discussed. The Fowler and Milne method was used to measure the temperature profile of the plasma under various conditions of gas flow and composition, and at several power levels. Measured peak temperatures ranged from  $14000^\circ$ - $19000^\circ$  K. The power losses from the plasma in the form of convection, radiation, and conduction to the nozzle walls were measured under the same conditions. Total power transferred to the plasma ranged from 1.6-3.1 kW which was approximately 50% of the input power. The extent to which local thermal equilibrium prevails in the plasma is discussed; the available evidence indicates that under the operating conditions described herein, equilibrium is closely approached.

7084 SYNCHROTRON RADIATION FROM MIRROR MACHINE GEOMETRIES. D.B.Beard and J.C.Baker.

Phys. of Fluids (USA), Vol. 4, No. 5, 611-18 (May, 1961).

The radiation due to the orbiting of electrons in a confining magnetic field has been numerically integrated over a thermal

velocity distribution perpendicular to the magnetic field as a function of frequency of emitted radiation and the angle the radiation propagation vector makes with the magnetic field. The general dependence of the emission on angle and frequency has been examined by the use of various approximations and is shown to agree with the numerical calculations. The result for a velocity distribution perpendicular to the magnetic field more nearly corresponds to Drummond and Rosenbluth's (Abstr. 3773 of 1960) previous angular dependence than with Trubnikov's result (Abstr. 4607 of 1961) for an isotropic velocity distribution.

#### 7085 VELOCITY-SPACE PLASMA INSTABILITIES OBSERVED IN A MIRROR MACHINE.

R.F.Post and W.A.Perkins.

Phys. Rev. Letters (USA), Vol. 6, No. 3, 85-9 (Feb. 1, 1961).

Plasma injected into a single-stage mirror machine was compressed by a magnetic field rising to  $\sim 1000$  times the initial value of  $\sim 10$  G. Scintillation probes detected fluxes of particles escaping in the radial and axial directions. Large radial fluxes, and direct observation of the radial plasma density distribution, showed excessive loss of up to  $10^7$  times collisional diffusion rates across the magnetic field, in certain conditions. The variation of the phenomena with injected plasma density, compression ratio and collision rates enhanced by introducing a background of neutral helium, and agreement between theoretical and experimental values of  $\beta$  for the onset of instabilities, indicate the velocity-space instabilities due to excessive anisotropy of the electron velocity, as first proposed theoretically by Rosenbluth [Los Alamos Report LA-2030 (1956)]. From the probe signals, it also appears that, in many cases, the most unstable parts of the plasma diffuse out rapidly, leaving behind a stable plasma which is only detected much later, when the main confining field falls.

R.S.Pease

## Plasma Oscillations

#### 7086 THEORY OF ELECTRON OSCILLATIONS IN NON-UNIFORM PLASMAS. M.Sumi.

J. Phys. Soc. Japan, Vol. 15, No. 1, 120-7 (Jan., 1960).

For a system consisting of a plasma and an externally injected beam with a non-uniform density and temperature, electron oscillations are described on the basis of linear macroscopic equations. In the one-dimensional case the spatially growing plasma wave and the standing plasma wave are discussed. It is found that in the former, a wave propagating towards decreasing density grows more rapidly than in the uniform case; in the latter the wavelength becomes shorter towards lower density and jumps of mode and frequency occur at a layer thickness of greater than that in a uniform plasma. In the increasing density direction the behaviour of the system is reversed. Finally, a brief account is given on the two-dimensional case.

#### 7087 ELECTRO-HYDROMAGNETIC WAVES IN A FULLY IONIZED GAS. I. K.D.Cole.

Planet. Space Sci. (GB), Vol. 1, No. 4, 319-24 (Sept., 1959).

Transport equations are used to determine coefficients which are generalizations for any frequency of electric field of the parallel, Pedersen and Hall conductivities in a fully ionized gas. These coefficients are used in an investigation of the propagation of weak electromagnetic and hydromagnetic waves of all frequencies across a homogeneous and constant magnetic field in a rarefied fully ionized gas. Relationships are deduced for propagation at any angle to the magnetic field for frequencies greater than about 10 times the gyrofrequency of electrons. The theory is applied to discuss transmission of disturbance across the interplanetary medium, the temperature of the solar corona and the earth's outer atmosphere, the emission of non-thermal solar radar noise, cosmic radio noise and the anomalous emission of light from shock fronts.

#### PLASMA OSCILLATIONS OF ELECTRON GASES.

See Abstr. 6093

## ELECTRON EMISSION ELECTRON BEAMS

#### NOISE IN ELECTRONIC DEVICES.

7088 London: Chapman and Hall (1961) 100 pp.

Seven papers based on material presented at a conference held by the Electronics Group of The Institute of Physics at Baldock in October, 1959. The papers vary from a concise yet complete account of noise phenomena, to some new considerations of noise in valves, and cover various particular electronic devices in between. They should be of value to students and research workers, both as an introductory text and possibly as a work of reference. The titles are: The physical basis of noise, F.J.Hyde (9-34; 30 refs); Noise in grid controlled valves, W.H.Aldous (35-49; 10 refs); Noise in transistors, F.Hibberd (50-7; 6 refs); Noise in masers and parametric amplifiers, P.N.Butcher (58-65; 10 refs); Low noise microwave amplifiers, C.P.Lea-Wilson (66-77; 12 refs); Current noise in fixed cracked carbon resistors, P.L.Kirby (78-85; 6 refs); The fluctuations in the characteristics of valves, C.S.Bull (86-98; 8 refs).

#### ELECTRON EMISSION FROM P-N JUNCTIONS.

7089 R.Goffaux.

J. Phys. Radium (France), Vol. 21, No. 2, 94-6 (Feb., 1960). In French.

The experimental relation between the reverse current and the electron emission current from p-n junctions, proposed by Patrick, is satisfactorily interpreted on the basis of the electron temperature. A good agreement exists between the theoretical and experimental values of the activation energy of donor centres and traps. Hot electron emission could be a useful mode of emission.

#### PHOTOELECTRIC EMISSION FROM SEMICONDUCTOR CLEAN SURFACES. See Abstr. 6146

#### IMAGE INTENSIFIERS FOR NUCLEAR TRACK

7090 IMAGING. R.G.Stoudenheimer,

R.G.Stoudenheimer, J.C.Moor and H.L.Palmer.

IRE Trans nuclear Sci. (USA), Vol. NS-7, No. 2-3, 136-41 (July-Sept., 1960). Proceedings of the Seventh Scintillation Counter Symposium, Washington, February, 1960.

Two- and three-stage electrostatically focused cascaded image converters were made specifically for the purpose of intensifying the tracks of nuclear particles passing through a scintillation chamber. Gains as high as 50 per stage were obtained with an input equivalent to screen background as low as  $10^5$  photons  $\text{cm}^{-2} \text{sec}^{-1}$  (slightly more than  $10^4$  photoelectrons  $\text{cm}^{-2} \text{sec}^{-1}$ ). At reduced voltage and gain, backgrounds were equivalent to about 100 electrons  $\text{cm}^{-2} \text{sec}^{-1}$  (the level of the thermionic emission). Scintillations of individual electrons were recognized. With a fast (P15) phosphor for the first screen, the microsecond image storage accompanied by microsecond pulsing of the applied voltage across the second stage made possible complete elimination of tube background in photographs of nuclear tracks.

#### 7091 THE TECHNOLOGY OF THE PRESENT-DAY TELEVISION CHARGE STORAGE TUBES, ORTHONIC AND SUPERORTHICON, SUPERICONOSCOPE, VIDICON.

F.Pilz.

SB Heidelberg Akad. Wiss. (math. nat. Kl.) (Germany), 1959, No. 5, 40-4. In German.

"Image convertors and storage tubes" meeting, Heidelberg, 1958 (see Abstr. 3004 of 1961). Briefly describes the mode of operation of each of the above camera tubes, its sensitivity together with various technical limitations. Reference is made to more complete treatises.

A.E.I. Research Laboratory

#### SECONDARY EMISSION MULTIPLIERS AND IMAGE CONVERTERS.

7092 A.Krohs.

SB Heidelberg Akad. Wiss. (math. nat. Kl.) (Germany), 1959, No. 5, 59-62. In German.

"Image convertors and storage tubes" meeting, Heidelberg, 1958 (see Abstr. 3004 of 1961). Short contribution to a discussion on signal/noise ratio and uniformity of cathode sensitivity of image convertors. Present techniques of manufacture enable a figure of  $\pm 8\%$  to be achieved for the latter. A universally applicable definition is proposed for image intensification in terms of the ratio of the energy (in watts) radiated from the fluorescent screen to that incident on the photocathode.

A.E.I. Research Laboratory

- 7093 **THE INFLUENCE OF MECHANICAL STRAIN ON THE SECONDARY ELECTRON EMISSION FROM BERYLLIUM OXIDE.** A.M.Tyutikov.  
Dokl. Akad. Nauk SSSR, Vol. 136, No. 5, 1063-5 (Feb. 11, 1961). In Russian.

The secondary electron emission from strained films of beryllium oxide was studied. The films (10 mm × 25 mm) were prepared by vacuum evaporation (5 × 10<sup>-7</sup> mm Hg) of beryllium followed by controlled oxidation to a thickness of some hundred angstroms. They could be strained mechanically by a device within the vacuum. The 400 V primary electron beam of 1 mm diameter was deflected to fall on the centre of a specimen. The results indicate a tendency for the potential at which the current-voltage characteristic saturates to increase with compression of the film, removal of the strain resulting in re-establishment of the original characteristic over a certain range, beyond which the film became fatigued. An explanation of the changes observed is tentatively given in terms of defects of the crystal lattice occurring during the deformation of the film. [English translation in: Soviet Physics—Doklady (USA)].

V.R.Switsur

- 7094 **NON-LINEAR THERMAL FLUCTUATIONS IN A DIODE.** N.G.van Kampen.  
Physica (Netherlands), Vol. 26, No. 8, 585-604 (Aug., 1960).

As an example of non-linear noise the fluctuations in a circuit consisting of a diode and a condenser C are studied. From the master equation for this system the following results are derived. (i) The equilibrium distribution of the voltage is rigorously Gaussian, the average voltage being equal to the contact potential of the two electrodes. (ii) The ordinary I-V characteristic of the diode is found in the limit  $C \rightarrow \infty$ . (iii) An expansion in  $e^2/kTC$  is used to find the spectral density of the fluctuations to first order. It is shown that to this order the Fokker-Planck equation gives the same result. (iv) Another approximation method leads to an expansion of the fluctuation spectrum in inverse powers of the frequency. It is rigorously shown that the first term in this expansion is not affected by the presence of the non-linearity. (v) The so-called fluctuation-dissipation theorem is not valid beyond the linear approximation. (vi) The expansion of the fluctuation spectrum in  $e^2/kTC$  can be calculated to all orders. However, the complete spectrum contains additional terms, which do not show up in this expansion, as they are of infinite order in  $e^2/kTC$ .

- 7095 **THE USE OF SINGLE ELECTRON LENSES AS HIGH POWER ENERGY FILTERS FOR ELECTRON BEAMS.** K.Keck and H.Diechsel.  
Optik (Germany), Vol. 17, No. 8, 401-8 (Aug., 1960). In German.

Single electron lenses are used in electron microscopy as high resolution filters. In the present paper, the extent to which a single electron lens can be used as an energy filter, for electron beams with fairly large cross-section, if high resolution is sacrificed, is investigated. In addition, the paths of the electrons within the single lens are calculated.

- 7096 **AN ELECTRON MICROSCOPE WORKING AT A VERY HIGH VOLTAGE.** G.Dupouy, F.Perrier and R.Fabre.  
C.R. Acad. Sci. (France), Vol. 252, No. 5, 627-2 (Jan. 30, 1961).

An important paper in electron microscopy, since the advantages (examination of living specimens, thick specimens, at high resolution) are now realizable. A 1.5 MV instrument housed in a special laboratory is described, using four stages of magnetic lenses. Objective focal length at 1.0 MV is 5.5 mm. The working column alone is 8 m high, more than 60 cm in diameter and needs a mobile platform to operate its controls. Its essential parts are carefully shielded from X-radiation. Actual results are most impressive but may be improved by reducing column vibration and by better regulation of the high voltage.

R.Reed

- 7097 **THE USE OF A SEMI-INCOHERENT ILLUMINATION FOR OBSERVATION OF AMORPHOUS OBJECTS IN THE ELECTRON MICROSCOPE.** P.Selme.  
C.R. Acad. Sci. (France), Vol. 252, No. 9, 1293-5 (Feb. 27, 1961).

Electron microscopes are normally used with strongly coherent illumination and this can sometimes lead to incorrect interpretation of the images. A study was made of the reproduction in the electron microscope of conditions of incoherent illumination as in the optical microscope. The conditions necessary for the experimental realization include the use of a large condenser angular aperture; reduced cross-over brilliance; an objective lens of low spherical and chromatic aberration; a suitable objective aperture in the image

plane; good centring of the illuminating system and the positioning of the specimen on the support on the side away from the source. Resolution of the order of 10 Å with good contrast in images of amorphous objects was obtained.

V.R.Switsur

- 7098 **RESOLVING POWER AND LUMINOSITY OF A  $\beta$ -SPECTROGRAPH, USING A MAGNETIC FIELD VARYING AS  $R^{-1}$ .** C.Bastard and J.Lafauciere.  
J. Phys. Radium (France), Vol. 21, No. 2, 112-14 (Feb., 1960). In French.

In earlier work (Abstr. 4709 of 1959; 19756 of 1960) the characteristics of a  $\beta$ -spectrograph were studied using an inhomogeneous magnetic field of constant rH. Now, the position of the diaphragms, the resolving power and the luminosity are studied, the latter being excellent but the resolving power being limited by the dimensions of the spectrograph.

- 7099 **REFLECTION OF SLOW ELECTRONS FROM TUNGSTEN SINGLE CRYSTALS, CLEAN AND WITH ADSORBED MONOLAYERS.** P.Kisliuk.  
Phys. Rev. (USA), Vol. 122, No. 2, 405-11 (April 15, 1961).

The reflection of electrons with kinetic energy up to a few electron volts from tungsten single-crystal surfaces was measured, both on the clean surface and with adsorbed monolayers of nitrogen and oxygen. For the clean surface, diffraction from the lattice is responsible for a considerable part of the reflection in the thermionic range of energy. The magnitude of the reflection is such as to have a barely measurable effect on experimental tests of the thermionic emission equations. This technique permits continuous recording of the change in work function as gas is adsorbed, yielding information about the kinetics of chemisorption and the surface dipoles due to the adsorbed gas atoms.

- 7100 **MODIFIED FLAMMERSFELD RANGE ENERGY RELATION FOR ELECTRONS.** S.P.Khare and Y.P.Varshni.  
Ann. Phys. (Germany), Vol. 7, No. 3-4, 220-4 (1961).

The Flammersfeld relation for electrons in Al was shown by Varshni and Karnatak (Abstr. 4714 of 1959) to be satisfactory only above 0.2 MeV energy. In the present work, the relation, after suitable modification, is extended to the low energy region. The modified relation yields satisfactory results down to 2 keV and passes smoothly to its original form above 0.2 MeV. The observed values are compared with the theoretical results of Nelms (1956). For a given energy, the observed range is smaller than the theoretical range.

- 7101 **ANOMALOUS TRANSMISSION OF ELECTRONS IN A FILM OF MOLYBDENITE.** K.Kohra and H.Watanabe.  
J. Phys. Soc. Japan, Vol. 14, No. 8, 1119-20 (Aug., 1959).

Shows examples of anomalous transmission of 75 kV electrons through thick films of molybdenite by electron diffraction. The mechanism of this process is thought to be analogous to the anomalous transmission of X-rays through thick nearly-perfect crystals.

A.E.I. Research Laboratory

- 7102 **TRANSMISSION OF SLOW ELECTRONS THROUGH THIN FILMS.**

O.Klemperer and A.Thetford, with a note by F.Lenz.  
Proc. Phys. Soc. (GB), Vol. 76, Pt 5, 705-14, 714-20 (Nov., 1960).

The transmission of electrons with energies of 600-6000 eV through films of aluminium and of aluminium oxide of 180-1100 Å thickness was investigated. The transmittance was measured for angles of acceptance between 18° and 36° and the results were compared with Bothe's formula. The range of the electrons as a function of their initial energy was found by extrapolation. Energy distributions for electrons transmitted through the films were measured and values for the transmitted energies as a function of the primary energy and of the film thickness were compared with the available theoretical results. Some modifications of Bothe's theory of multiple scattering in the region of low electron energies are suggested and numerical values for the relevant correction factor are calculated. In this way the discrepancies between the theory and the experimental results presented in the paper are considerably reduced.

- CHARACTERISTIC ELECTRON ENERGY LOSSES IN TEN ELEMENTS.** See Abstr. 6100

**A PHENOMENOLOGICAL THEORY OF THE CHARACTERISTIC ENERGY LOSSES OF FAST ELECTRONS IN METAL.** See Abstr. 6099

## ION EMISSION . ION BEAMS

## 7103 EMISSION OF NEGATIVE IONS OF OXYGEN FROM DISPENSER CATHODES. I. CATHODES OF BARIUM OXIDE IN SINTERED NICKEL. N.A.Surplice.

Brit. J. appl. Phys., Vol. 12, No. 5, 214-19 (May, 1961).

Cathodes of sintered nickel and barium oxide were used as ion sources in simple mass spectrometers and were found to emit negative ions of atomic oxygen for at least 24 hours during their activation at 1250-1350°K. The evidence suggests that the oxygen is produced by the dissociation of barium oxide and is removed from the cathode by positive ion bombardment. At voltages greater than the ionization potentials of the residual gases, the variation of the oxygen ion current  $I$  with time  $t$  could be expressed as the sum of two exponentially decreasing terms:  $I = a \exp(-pt) + b \exp(-qt)$ , where  $p$  and  $q$  were of the order of 2 and 0.2 per hour respectively. Similar results have been obtained with a commercial cathode containing triple carbonates. There appear to be two processes operating in parallel, corresponding to the two terms of the equation. It is postulated that the first process is the diffusion of oxygen through the bulk of the crystals to the nickel part of the cathode's surface, and its removal from there by bombardment with positive ions of oxygen and nitrogen. The second process is the diffusion of oxygen through the pores of the cathode, and its removal from the ends of pores by bombardment with positive ions of barium as well as of the residual gases. The first process has the slower rate of replacement of oxygen and in an hour or two this process is insignificant compared with the second one. If the cathode's surface is temporarily poisoned with oxygen from an external source then it rids itself of the extra oxygen within a few seconds.

## 7104 EMISSION OF NEGATIVE IONS OF OXYGEN FROM DISPENSER CATHODES. II. CATHODES OF BARIUM ALUMINATE IN SINTERED TUNGSTEN. N.A.Surplice.

Brit. J. appl. Phys., Vol. 12, No. 5, 220-1 (May, 1961).

A cathode of sintered tungsten impregnated with barium aluminate was studied in a simple mass spectrometer and was found to emit negative ions of oxygen. About 90% of the oxygen ions were in the atomic form and 10% in the molecular form. The experiments showed that the ions come from an adsorbed layer of oxygen on the tungsten matrix, from which they are removed by bombardment with positive ions, chiefly of nitrogen. Similar results were obtained with a tungsten matrix without any impregnant.

## 7105 MEASUREMENTS ON THE PROPERTIES OF A SIMPLE OMEGATRON. D.S.Stark.

Vacuum (GB), Vol. 9, No. 5-6, 288-94 (Nov. - Jan., 1960).

Measurements have been made on a simple omegatron mass spectrometer, to show the effect of various parameters on the sensitivity, resonant frequency, resolution and background ion current. Increase of magnetic field has been shown to cause a marked improvement in peak-to-background ratio, and to improve resolution approximately as predicted by the simple theory. The range has been extended to include Hg, the height of Hg peaks having been shown to be proportional to the pressure of Hg vapour present. Using the results it has been possible to make a practical appraisal of the sensitivity of the omegatron as a leak detector. This leads to less optimistic sensitivity values than have been quoted on theoretical grounds.

7106 THE RANGE OF Na<sup>24</sup> IONS OF KILOELECTRON VOLT ENERGIES IN ALUMINUM. J.A.Davies and G.A.Sims.

Canad. J. Chem., Vol. 39, No. 3, 601-10 (March, 1961).

Detailed studies are reported for the depth of penetration in aluminium of monoenergetic Na<sup>24</sup> ions over the energy region 0.7-60 keV. Below 20 keV the median range ( $R_M$ ) increases linearly with energy as predicted by the Bohr-Nielsen equation. As was observed in a previous study with Cs<sup>137</sup> ions in aluminium, the experimental distribution curves are not Gaussian in shape, but consist of a markedly asymmetric peak followed by a pronounced exponential "tail". The results of a Monte Carlo calculation show that the observed distribution curves correspond quite closely to those predicted by an isotropic elastic-scattering model. Above 20 keV, a slight deviation from the linear range-energy relationship is observed; also, the distribution curves become narrower and more symmetrical, suggesting that electronic interactions are starting to play a significant role in the stopping process. Some preliminary

results for the range of accelerated ions of Rb<sup>86</sup> and K<sup>42</sup> in aluminium are also included for comparison. Median ranges for each of the alkali metal ions are compared with those predicted by the Bohr-Nielsen treatment.

7107 RANGE OF Li<sup>8</sup> IONS OF 40-450 keV ENERGY IN HYDROGEN, DEUTERIUM AND HELIUM.

H.G.Clerc, H.Wäffler and F.Berthold.

Z. Naturforsch. (Germany), Vol. 16a, No. 2, 149-54 (Feb., 1961). In German.

The range-energy relations were determined for H<sub>2</sub>, D<sub>2</sub> and He as stopping gas. The results for H<sub>2</sub> and He are in satisfactory agreement with the stopping cross-sections of Li<sup>7</sup> ions, as determined by Allison and Littlejohn (Abstr. 2338 of 1957). If the effect of nuclear elastic collisions is taken into account, the experimental differences between the ranges in H<sub>2</sub> and D<sub>2</sub> follow closely the theoretical predictions of Bohr (1948). An extension of the range-energy relation for Li ions of mass 6 and 7 is presented.

## 7108 SPUTTERING OF SOLIDS BY PENETRATING IONS. R.S.Pease.

"Plasma physics", Varenna Summer School, 1959 (see Abstr. 5438 of 1961), p. 158-65.

Gives theoretical expressions for sputtering ratios as a function of the mass, charge and energy of the impinging ion and target material, for the case where the ion penetrates the surface layers with unaltered momentum. The calculations are based on the radiation damage theory of Kinchin and Pease (Abstr. 1417 of 1956), and neglect the effects of crystal structure. The theoretical values agree to within a factor of two with experimental results of O'Brian et al. (Abstr. 1541 of 1959) for sputtering of silver by H, D and He ions of about 10 keV energy.

R.S.Pease

## 7109 MERCURY ION BEAM SPUTTERING OF METALS AT ENERGIES 4-15 keV. G.K.Weherner and D.Rosenberg.

J. appl. Phys. (USA), Vol. 32, No. 5, 887-90 (May, 1961).

Sputtering yields for 14 metals from the 4th, 5th, and 6th periods were measured for normally incident Hg<sup>+</sup> ions at energies between 4-15 keV. The sputtering rate was determined by measuring the time required for the ion beam to pierce a target foil. Results for the various metals show that yields at high energy behave similarly to yields previously found at lower ion energy; i.e., are closely linked to the position of the metal in the periodic chart. Yields increase in the 4th period from Ti through V, Fe, Co, Ni to Cu and in a similar fashion in the 5th period to Ag and in the 6th period to Au. It is believed that Cu, Ag, and Au atoms with their more closely filled d shells behave more nearly like hard spheres and always produce the highest sputtering yields.

## 7110 DETERMINATION OF THE MAXIMUM LATTICE-CHAIN ENERGY FROM SPUTTERING YIELD CURVES. D.E.Harrison, Jr.

J. appl. Phys. (USA), Vol. 32, No. 5, 924-7 (May, 1961).

An analysis is presented which suggests that the "ankle energy", that is, the energy at which the experimental sputtering ratio curve begins to form a low-energy tail, is the maximum energy which the metallic lattice can propagate in a close-packed direction. The effect appears to depend only upon the existence of a chaining threshold, and not upon the mathematical model of the sputtering process. The equivalence is demonstrated for the author's statistical model, and for the primary lattice ion model of Kinchin and Pease (Abstr. 1417 of 1956).

## PARTICLE ACCELERATORS

## 7111 KINEMATIC EFFECTS IN TARGET THICKNESS CALCULATIONS. I.Naqib and D.K.McDaniels.

Rev. sci. Instrum. (USA), Vol. 31, No. 12, 1358-60 (Dec., 1960).

Extends the work of Cohen (Abstr. 8238 of 1959) on the effect of target energy loss on resolution to the case of light residual target nuclei.

J.W.Sturgess

## 7112 QUANTUM EXCITATION AND RADIATIONAL DAMPING OF ELECTRON OSCILLATIONS IN CYCLIC ACCELERATORS. F.A.Korolev, O.F.Kulikov and A.G.Eršov.

Nuovo Cimento (Italy), Vol. 18, No. 5, 1033-6 (Dec. 1, 1960).

Experimental confirmation of the theories of Sokolov, Ternov and Ivanenko (Abstr. 3980 of 1957) and Kolomenskii and Lebedev

[Abstr. 8230 of 1956 and Atomnaya Energiya (USSR), Vol. 4, 31 (1957)] was obtained on a 660 MeV electron synchrotron. Fast photographs of the radiation emitted by the accelerated electrons were investigated photometrically. Agreement is good but not exact. Undamped axial oscillations were observed. At over 550 MeV an increase in axial beam width and a decrease in radial width were observed. Neither of these is predicted by theory.

J.W.Sturgess

**A 160 cm SYNCHRO- AND VARIABLE ENERGY ORDINARY CYCLOTRON.** S.Kikuchi, I.Nonaka, H.Ikeda, H.Kumagai, Y.Saji, J.Sanada, S.Suwa, A.Isoya, I.Hayashi, K.Matsuda, H.Yamaguchi, T.Mikumo, K.Nishimura, T.Karasawa, S.Kobayashi, K.Kikuchi, S.Ito, A.Suzuki, S.Takeuchi and H.Ogawa. J. Phys. Soc. Japan, Vol. 15, No. 1, 41-59 (Jan., 1960).

A 160 cm cyclotron has been constructed as the first accelerator of the Institute for Nuclear Study, University of Tokyo. This cyclotron can be used as a variable energy ordinary cyclotron as well as a synchrocyclotron by changing the dee-system and the oscillator system. As an ordinary cyclotron it can produce protons of any desired energy between 7.5 and 15 MeV, deuterons between 15 and 21 MeV, and  $\alpha$ -particles between 30 and 42 MeV. These beams are now being used for various experiments on nuclear reactions and for production of radio-isotopes. As a synchrocyclotron, it can produce protons of 57 MeV in energy and the beam is extracted with high efficiency at a radius near  $n = 1$  with an electrostatic deflector.

## MAGNETISM

*(The magnetic properties of solids are included under Solid-State Physics; similarly for Liquid State and Gaseous State)*

### A NUCLEAR MAGNETOMETER.

**7114** G.Faini, A.Fuortes and O.Svelto. Energia nucleare (Italy), Vol. 7, No. 10, 705-16 (Oct., 1960).

Describes the design and the testing of an apparatus for the measurement of the earth's magnetic field, based on the principle of nuclear induction. The method uses the pre-polarization technique of Packard and Varian that has proved to be best suited for measurements of weak magnetic fields; but differs slightly by using relatively strong pre-polarization of the nuclear sample, followed by a small and sharp "rotation" field. Particular care was given to the maximization of the signal-to-noise ratio, and to the extraction of the maximum information from the nuclear signal. In this way, it was possible to obtain an accuracy of  $10^{-5}$  for absolute measurements and  $10^{-6}$  for relative ones. In conclusion, the results of some measurements are discussed.

### M-H LOOP TRACER FOR CIRCUMFERENTIAL FIELDS.

**7115** G.F.Schrader. Rev. sci. Instrum. (USA), Vol. 32, No. 4, 429-32 (April, 1961).

An apparatus has been constructed to measure the M-H characteristics of thin magnetic films plated on a nonmagnetic wire substrate. The films were uniaxially anisotropic and the characteristics were to be measured in the circumferential direction. Cancellation of air coupling and spurious noises was accomplished by means of a bridge circuit which used magnetic coupling to provide the necessary isolation for the various signals. The characteristics of the bridge are derived.

### MEASUREMENT OF PERMEABILITY TENSOR OF FERRITES AT 3000 AND 8500 Mc/s.

**7116** F.Dachert and A.Schmouchkovitch. J. Phys. Radium (France), Vol. 21, Suppl. No. 3, 57A-64A (March, 1960). In French.

Describes apparatus for the measurement of the permeability tensor of ferrites at wavelengths of 3 and 10 cm. The device used at 10 cm is novel. As an example, results are given of a series of measurements made at 3000 and 8500 Mc/s on manganese-magnesia ferrites.

**AUTOMATIC COMPENSATION FOR THERMAL E.M.Fs AND GALVANOMETER ZERO DRIFT IN A FEEDBACK FLUX-METER.** See Abstr. 7006

### GENERATION OF VERY STRONG PULSED MAGNETIC FIELDS.

**7117** I.G.Fakidov and É.A.Zavadskii. Fiz. Metalov i Metallovedenie (USSR), Vol. 6, No. 3, 569 (1958). In Russian.

A pulsed magnetic field apparatus capable of producing fields up to 500 000 Oe inside a single-layer coil is reported. The uniformity is 1.5% within a cylindrical volume of 6.5 mm diameter and 5 mm height. The current supply is a capacitor bank of 1600  $\mu$ F discharged from 3000 V. The discharge is oscillatory with a frequency of 2.8-3.0 kc/s. The apparatus has been used to study the effect of transverse magnetic fields on the electrical conductivities of n- and p-type germanium at 300°K, 77°K and 20°K. The results of the measurements and a detailed description of the apparatus will be given later. [English translation in: Metals and Metallography (USSR), Vol. 6, No. 3, 180 (1958)]. S.A.Ahe

### TYPICAL FAILURES IN PULSED MAGNET COILS.

**7118** R.Stevenson. Canad. J. Phys., Vol. 39, No. 2, 367-9 (Feb., 1961).

Describes the construction and causes of failure in coils made from beryllium-copper when used to produce magnetic fields of the order of  $10^6$  Oe. Mechanical failure occurs usually in fields in excess of  $8 \times 10^5$  Oe. R.Park

### HALL-EFFECT INSTRUMENTS FOR LABORATORY AND ROUTINE CHECK OF PERMANENT MAGNETS.

**7119** C.R.Henning. Ferromagnetism Working Party, Berlin, 1959 (see Abstr. 18171 of 1960) p. 234-40. In German.

A review and description of Hall generators and their use in the measurement of magnetic properties. D.S.Paras

**ELONGATED IRON-COBALT FERRITE: A NEW, LIGHT-WEIGHT, PERMANENT MAGNET MATERIAL.** See Abstr.

**DEVELOPMENT OF ELONGATED PARTICLE MAGNETS.** See Abstr. 6341

### MAGNETIC FILM DEVICES USING PASSIVE LOADING.

**7120** J.M.Daughton, T.A.Smey, A.V.Pohm and A.A.Read. J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 36S-37S (March, 1961). Computer solutions of a pair of differential equations based on the Landau-Lifshitz model indicate that with passive loading, magnetic film devices may be used as storage and logical elements in digital computers. Experimental models of a flip-flop consisting of an R-C-L loaded film device show that successive 20 Oe, of 0.1  $\mu$ sec drive field pulses can switch the magnetization in the film alternately from one rest orientation to the other with repetition rates of the drive on the order of  $10^6$  pulses/sec. A non-destructive readout memory element consisting of an R-L loaded thin film device is shown which allows films with  $H_K$  on the order of 3 Oe to be driven in the hard direction by 15 Oe, 0.05  $\mu$ sec field pulses without destroying the stored information, resulting in output voltages of about 25 mV per winding turn. Fabrication by evaporation techniques of a memory employing such elements is discussed.

### FLUX DISTRIBUTION IN FERRITE CORES UNDER VARIOUS MODES OF PARTIAL SWITCHING.

**7121** R.H.James, W.M.Overn and C.W.Lundberg. J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 38S-39S (March, 1961). This paper describes the flux distribution in a ferrite core after partial switching to the same flux density by three different methods: (1) by applying a fixed pattern of alternate-polarity pulses with diminishing amplitude; (2) by amplitude limiting; and (3) by time limiting. Discontinuities in the residual magnetization curve in the first case show the existence of regions of oppositely-directed magnetization. A comparison of the curves shows that the time-limited state can be represented by a model consisting of a large number of regions magnetized in alternate directions.

### IMPULSE SELECTION FOR CORE LOGIC.

**7122** R.H.Tancrell. J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 40S-41S (March, 1961). Impulse selection is a scheme for operating ferrite cores which have low values of coercive force. Two different threshold properties of a core are utilized. One threshold is the d.c. coercive force which can be changed electrically. The other threshold results from the inertial magnetic effects within the core which are predominant when pulses of very narrow widths are applied. The switching behaviour of ferrite cores is discussed when two threshold currents, a low amplitude current and an impulse of current, are combined. The application of this property to core logic is considered.

## MAGNETIC COMPUTER ELEMENTS. See Abstr. 6690

7123 RECORDING AND REPRODUCTION OF NRZI  
[MODIFIED NONRETURN TO ZERO] SIGNALS.

R.S.Schools.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 42S-43S (March, 1961).

A systematic theoretical study of a saturation type of recording and reproduction in digital magnetic tape systems was undertaken so that the details of these processes could be more clearly understood. The dependence of tape magnetization and of output signal pulse width and amplitude on the major system parameters was determined. These parameters are the magnetic field distribution of the recording head, write current waveform, tape thickness and hysteresis characteristics, head-to-tape spacing, reading gap length, and bit density. A portion of this study is presented, concerning the extension of the sinusoidal theory to include the reproduction of signals resulting from saturation recording. This is done by a Fourier analysis of the tape magnetization and a term-by-term summation of harmonic responses to obtain the resultant signal. The results show why high writing field gradients, high tape B-H "squareness", and thin tapes are needed for high-density recording. They indicate possible reasons for e.m.f. pulse peak position asymmetries during readback. Two examples of output calculations are included. One shows the signal amplitude and pulse width versus bit density, compared with experimental measurements. The other presents the field distribution above the magnetized tape, indicating the influence of the presence of the read head.

## DEMAGNETIZATION OF TWISTOR BITS.

7124 W.A.Barrett.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 35S-36S (March, 1961).

The storage of binary information in twistor wire is complicated by the presence of demagnetizing fields resulting from the open flux path structure of this device. These fields modify the writing threshold of each bit and contribute an interaction with neighbouring bits on the same wire. The effect of these demagnetizing fields has been measured with a search-coil technique. A simple procedure consisting of a coincident-current bit select followed by a single-current read select is used to form and "erase" the magnetized regions. It is found that the shape of the magnetized regions thus formed are a complex function of the two currents used and that the bits are not fully erased by the single current. The results suggest that demagnetization must be reduced by reducing thickness and/or bit density unless a more complex solenoid structure can be found to control the magnetization of the bit regions.

ELECTROMAGNETISM  
MAGNETOHYDRODYNAMICS7125 DERIVATION OF THE DISPLACEMENT CURRENT  
FROM THE BIOT-SAVART LAW. A.Bierman.

Amer. J. Phys., Vol. 29, No. 6, 355-6 (June, 1961).

A calculation of the curl of B starting with the Biot-Savart law leads directly to the inclusion of the displacement current into Maxwell's equations; one must assume slowly moving charges, slowly varying currents, and a neglect of the radiation field at large distances and after a long time.

## NULL ELECTROMAGNETIC FIELDS.

7126 I.Robinson.

J. math. Phys. (USA), Vol. 2, No. 3, 290-1 (May-June, 1961).

It is shown that a field of null rays is geodesic and shear-free if and only if the associated family of null bivectors includes a solution to Maxwell's equations for charge-free space.

NONLINEAR ELECTRODYNAMICS IN GENERAL RELATIVITY.  
See Abstr. 6775A UNIQUENESS THEOREM FOR THE EQUATIONS OF  
MAGNETOHYDRODYNAMICS. I.Ferrari.

Atti Semin. Mat. Fis. Univ. Modena (Italy), Vol. 9, 205-17 (1959-60). In Italian.

A viscous incompressible imperfectly conducting fluid is considered. The displacement and convection currents are neglected. The initial values of H and v throughout a given domain, together with the values of v and of the tangential component of H on the surface of the domain at all times, are shown to determine a unique solution of the magnetohydrodynamic equations. O.Penrose

VISCOUS MAGNETOHYDRODYNAMIC BOUNDARY  
LAYER. A.Sherman.

7128

Phys. of Fluids (USA), Vol. 4, No. 5, 552-7 (May, 1961).

The behaviour of the Blasius boundary layer, for a fluid of constant electrical conductivity, in the presence of a nonuniform magnetic field is studied. Distortion of the applied field due to currents flowing in the fluid is neglected; that is, the magnetic Reynolds number is assumed to be zero. Since the fluid is of uniform conductivity, the influence of the pressure distribution, caused by the interaction between the magnetic field and the inviscid flow, on the boundary layer is taken into account along with the Lorentz body force within the layer itself. The nonlinear boundary layer equations are solved by the method of power series expansion utilizing the Görtler variables. Particular attention is given to the case in which the nonuniform field is established in a constant height channel. The boundary layer, then, is assumed to begin at some position along one wall, and grow in the downstream direction. For purposes of computation, the problem is further specialized to treat the case in which the nonuniform field is generated by a current-carrying wire imbedded in one wall of the channel and aligned normal to the flow. The results of a calculation, for one choice of the relevant nondimensional parameters, show that the reduction in skin friction is sufficient to separate the boundary layer.

7129 SELF-SIMILAR SOLUTIONS OF THE EQUATION OF A  
LAMINAR BOUNDARY LAYER IN MAGNETO-  
HYDRODYNAMICS. N.I.Pol'skii and I.T.Shvets.

Dokl. Akad. Nauk SSSR, Vol. 136, No. 5, 1051-4 (Feb. 11, 1961). In Russian.

The method of self-similar solutions is used to reduce the partial differential equations of a laminar magnetic boundary layer in an incompressible viscous thermally conducting fluid to ordinary differential equations. The problem of a compressible fluid with Prandtl number close to 1 is also treated, using the method previously applied by Dorfman et al. [Priklad. Mat. i Mekh., Vol. 22, 274 (1958)] for the case with no magnetic field. [English translation in: Soviet Physics-Doklady (USA)]. O.Penrose

7130 ON THE FLOW OF A CONDUCTING FLUID PAST A  
MAGNETIZED SPHERE. G.S.S.Ludford and J.D.Murray.

J. Fluid Mech. (GB), Vol. 7, Pt 4, 516-28 (1960).

In the steady flow of an incompressible, inviscid, conducting fluid past a magnetized sphere, the first-order effects of the magnetic field and the conductivity are studied. Paraboloidal wakes of vorticity and magnetic intensity are formed, the former being half the size of the latter. The vorticity, generated by the non-conservative electromagnetic force, is logarithmically infinite on the sphere. For the case of a dipole of moment M at the centre of a sphere of radius a, the drag coefficient is

$$C_D = \frac{144\mu'^2}{5(2\mu + \mu')^2} \beta R_M$$

where  $\mu$  and  $\mu'$  are the permeabilities of the fluid and sphere, respectively,  $\beta$  is the ratio of the representative magnetic pressure  $\mu M^2/2a^3$  to the free-stream dynamic pressure, and  $R_M$  is the magnetic Reynolds number.

## MAGNETOHYDRODYNAMIC FLOW PAST A SPHERE.

7131 K.Gotoh.

J. Phys. Soc. Japan, Vol. 15, No. 1, 189-96 (Jan., 1960).

The flow of an incompressible, viscous, electrically conducting fluid past a sphere in the presence of a uniform magnetic field parallel to the undisturbed flow is investigated using Oseen approximation. The drag coefficient is calculated up to the second order of magnitudes of the following parameters: the Reynolds number R, the magnetic Reynolds number  $R_m$  and the Hartmann number M. Its numerical values are shown graphically for a few typical cases. It is found that the drag coefficient is continuous at the pressure number  $S = 1$ , whereas it changes there abruptly in the two-dimensional case. The flow pattern changes remarkably according as the pressure number  $S \gtrless 1$ .

7132 INSTABILITY OF CONDUCTING FLUID CYLINDER DUE  
TO AXIAL CURRENT. G.S.Murty.

Ark. Fys. (Sweden), Vol. 18, Paper 14, 241-50 (1960).

The stability of an incompressible, inviscid, electrically conducting fluid cylinder in the presence of axial current is considered taking into account the effect of surface tension. The effect of gravity is taken into account approximately. The results are found to be in reasonable agreement with experiment.

**7133 GENERAL THEORY OF ELECTRICALLY CONDUCTING PERFECT GAS FLOW PAST A THREE-DIMENSIONAL THIN BODY.** S.Ando.

J. Phys. Soc. Japan, Vol. 15, No. 1, 157-67 (Jan., 1960).

The fundamental equation for a parametric function is derived. The magnetic field, the flow velocity and the pressure are all related to the parametric function, and so the boundary conditions for the fundamental equation can be written explicitly. The flow over a wavy wall is treated as an application of the present theory in which the applied magnetic field may be in an arbitrary direction.

**7134 TWO-DIMENSIONAL FLOW OF AN IDEAL GAS WITH SMALL ELECTRIC CONDUCTIVITY PAST A THIN PROFILE.** T.Sakurai.

J. Phys. Soc. Japan, Vol. 15, No. 2, 326-33 (Feb., 1960).

Two dimensional flow of an ideal gas with small electric conductivity past a thin profile is investigated. The applied uniform magnetic field is assumed to make a small angle with the uniform flow at infinity. The usual thin wing expansion technique is applied and the linearized equation is derived. The linearized equation is solved for the case of flow past a symmetric profile using an approximate method similar to that of Oseen in the theory of viscous flow, and the first order effects of the conductivity and of the angle of inclination are examined. The subsonic as well as the supersonic flow cases are considered, and the lift and the drag due to the magnetic field are obtained. In the subsonic case, the lift vanishes while the drag is positive for any profile. In the supersonic case, the lift is found to be negatively proportional to the angle of inclination, while the drag is not affected by the presence of the magnetic field. An intuitive explanation of the results is also included.

**7135 A LINEARIZED THEORY OF MAGNETOHYDRODYNAMIC FLOW PAST A FIXED BODY IN A PARALLEL MAGNETIC FIELD.** H.Yosinobu.

J. Phys. Soc. Japan, Vol. 15, No. 1, 175-88 (Jan., 1960).

Reports a study of the flow of a viscous, incompressible and electrically conducting fluid past a fixed body in the presence of a parallel magnetic field. A perturbation method similar to Oseen approximation in ordinary hydrodynamics is applied to both the flow field and the magnetic field. It proves that the pressure number (the ratio of the magnetic pressure to the dynamic pressure) plays an important role in the main features of the field. Detailed calculations are carried out for the flow past a circular cylinder and an approximate formula for the drag per unit span of the cylinder is obtained.

**7136 THE DECAY OF MAGNETOHYDRODYNAMIC TURBULENCE.** P.H.Roberts and T.Tatsumi.

J. Math. Mech. (USA), Vol. 2, 697-713 (1960).

Equations are formulated for the evolution of the wave-number spectra of kinetic and magnetic energy in isotropic incompressible hydromagnetic turbulence under the dynamical approximation that fourth-order cumulants vanish for the joint distribution of simultaneous velocity and magnetic field amplitudes. A solution for a particular normal initial distribution is obtained to order  $R^2$ , where  $R$  is an appropriate turbulent Reynolds number. The authors admit non-vanishing initial correlation between velocity and magnetic fields, and find that the strength of this correlation importantly affects the asymptotic ratio of kinetic and magnetic energies at long times. [The reviewer would like to point out that, if the algebra is correct, the authors' results are quite independent of their dynamical approximation, to order  $R^2$ . To this order, they are exact consequences of the assumed normal initial state].

Mathematical Reviews (R.H.Kraichnan)

**7137 LOCAL HYDRAULIC RESISTANCES IN THE FLOW OF A LIQUID METAL [MERCURY] IN A TRANSVERSE MAGNETIC FIELD.**

G.Branover, R.Dukure, O.Lielausis and A.Tsinober.

Latv. PSR Zinat. Akad. Vestis (USSR), No. 11(160), 97-102 (1960). In Russian.

**7138 MAGNETOHYDRODYNAMIC WAVES IN A VISCOUS FLUID.** C.Totaro.

Atti Semin. Mat. Fis. Univ. Modena (Italy), Vol. 9, 13-23 (1959-60). In Italian.

Deals with small-amplitude Alfvén waves in a viscous incompressible imperfectly conducting fluid whose dielectric constant and magnetic permeability differ from 1. It is claimed, in particular, that when the applied magnetic field exceeds a certain critical value some waves grow spontaneously instead of decaying. O.Penrose

**7139 ON CYLINDRICAL MAGNETOHYDRODYNAMIC SHOCK WAVES.** C.Greifinger and J.D.Cole.

Phys. of Fluids (USA), Vol. 4, No. 5, 527-34 (May, 1961).

If an axial rod is surrounded by an ionized gas, an expanding cylindrical shock wave can be produced by passing through the gas a current which returns along the rod. The azimuthal magnetic field of the current acts like a piston, pushing the plasma away from the rod and leaving behind a cylindrical vacuum region. The case considered is that where a uniform magnetic field parallel to the axis is initially present in the gas; in this case a transverse magnetohydrodynamic shock wave results from the current discharge. The flow is analysed under the assumptions that the plasma is a non-viscous, non heat-conducting, ideal gas of infinite electrical conductivity, and that the discharge current increases linearly with time. The analysis is made first on the basis of the "snowplow" theory of Rosenbluth, and then from a similarity solution of the full magnetohydrodynamic equations. The results of the two solutions are compared for the case  $\gamma = 7/5$ . It is found that the speed predicted by the snowplow theory is in very good agreement with the speed of the contact front obtained from the solution of the full equations over the entire range of shock strength, but that the snowplow speed is a good approximation to the shock speed only in the limit of strong shocks. The effect on the flow of varying the axial field is discussed.

**IDEALIZED PROBLEMS OF PLASMA DYNAMICS RELATING GEOMAGNETIC STORMS.** See Abstr. 6654

**ON THE HYDROMAGNETIC WAVE-FRONTS IN THE SOLAR ATMOSPHERE. WAVE-FRONTS OF SMALL AMPLITUDE IN THE NONUNIFORM MEDIUM WITH WEAK MAGNETIC FIELD.** See Abstr. 6710

**MAGNETOHYDRODYNAMIC WAVE GENERATION IN AN ATMOSPHERE OF ARBITRARY ELECTRICAL CONDUCTIVITY.** See Abstr. 7155

**7140 END EFFECT LOSSES IN D.C. MAGNETOHYDRODYNAMIC GENERATORS.** R.A.Boucher and D.B.Ames.

J. appl. Phys. (USA), Vol. 32, No. 5, 755-9 (May, 1961).

The end effect loss in a d.c. magnetohydrodynamic generator with rectangular cross-section is considered. The case for non-conducting walls is examined, and a simple expression for the losses in terms of the maximum power output is obtained. The end effect loss is compared to viscous and turbulent flow losses and it is shown to be the predominant loss over a wide range of operating conditions.

## ELECTROMAGNETIC WAVES AND OSCILLATIONS

(See also Plasma Oscillations)

**7141 THE FERMAT PRINCIPLE IN THE FIVE-DIMENSIONAL THEORY.** S.Lederer.

C.R. Acad. Sci. (France), Vol. 252, No. 7, 991-3 (Feb. 13, 1961). In French.

Extends the work of Pham Mau Quan (Abstr. 4178 of 1956) to a five-dimensional medium and shows that in an isotropic medium the electromagnetic rays follow geodesics of zero length. Proposes that if the charge of a particle tends to zero more rapidly than its mass (e.g. a photon), then the first integral of the geodesic equation can be made to vanish.

J.K.Skwirzynski

**7142 EXCITATION OF VLF AND ELF RADIO WAVES BY A HORIZONTAL MAGNETIC DIPOLE.** J.Galejs.

J. Res. Nat. Bur. Stand. (USA), Vol. 45D, No. 3, 305-11 (May-June, 1961).

The v.l.f. and e.l.f. modes excited by a horizontal magnetic dipole (vertical loop) in the spherical shell between a finitely conducting earth and an isotropic sharply bounded ionosphere are shown to have a nearly transverse magnetic character. The modes are similar to those of a vertical electric dipole. With the exception of the zero-order mode, the propagating modes excited by the magnetic dipole are of slightly higher amplitudes, provided that the far fields of the horizontal magnetic and vertical electric dipoles are equal over flat earth in the absence of ionosphere. The transi-

fields generated by a current step in the magnetic dipole are in the first approximation similar to the fields generated by a current current impulse in a vertical electric dipole. Response of the zero-order mode of the magnetic dipole is calculated.

7143 **RESONANT MODES IN A MASER INTERFEROMETER.** A.G.Fox and T.Li.

Bell Syst. tech. J. (USA), Vol. 40, No. 2, 453-88 (March, 1961).

A theoretical study is made of the diffraction electromagnetic waves in Farby-Perot interferometers when they are used as resonators in optical masers. An electronic digital computer was programmed to compute the electromagnetic field across the mirrors of the interferometer where an initially launched wave is reflected back and forth between the mirrors. It was found that after many reflections a state is reached in which the relative field decays at an exponential rate. This steady-state field distribution is regarded as a normal mode of the interferometer. Many such normal modes are possible depending upon the initial wave distribution. The lowest-order mode, which has the lowest diffraction loss, has a high intensity at the middle of the mirror and rather low intensities at the edges. Therefore, the diffraction loss is much lower than would be predicted for a uniform plane wave. Curves for field distribution and diffraction loss are given for different mirror geometries and different modes. Since each mode has a characteristic loss and phase shift per transit, a uniform plane wave which can be resolved into many modes cannot be resonated in an interferometer. In the usual optical interferometers, the resolution is too poor to resolve the individual mode resonances and the uniform plane wave distribution may be maintained approximately. However, in an oscillating maser, the lowest-order mode should dominate if the mirror spacing is correct for resonance. A confocal spherical system is also investigated and the losses are shown to be orders of magnitude less than for plane mirrors.

7144 **CONFOCAL MULTIMODE RESONATOR FOR MILLIMETER THROUGH OPTICAL WAVELENGTH MASERS.** G.D.Boyd and J.P.Gordon.

Bell Syst. tech. J. (USA), Vol. 40, No. 2, 489-508 (March, 1961).

Multimode resonators of high quality factor will very likely play a significant role in the development of devices, such as the maser, which operate in the millimeter through optical wavelength range. It has been suggested that a plane-parallel Fabry-Perot interferometer could act as a suitable resonator. In this paper a resonator consisting of two identical concave spherical reflectors, separated by any distance up to twice their common radius of curvature, is considered. Mode patterns and diffraction losses for the low-loss modes of such a resonator are obtained analytically, using an approximate method suggested by W.D.Lewis (unpublished). The results show that the diffraction losses are generally considerably lower for the curved surfaces than for the plane surfaces. Diffraction losses and mode volume are a minimum when the reflector spacing equals the common radius of curvature of the reflectors. For this case the resonator may be termed confocal. A further property of the concave spherical resonator is that the optical alignment is not extremely critical.

7145 **AMPLIFICATION THROUGH STIMULATED EMISSION THE MASER.** R.A.Smith.

Brit. J. appl. Phys., Vol. 12, No. 5, 197-206 (May, 1961).

The various factors which determine the ultimate sensitivity of a radio receiver are considered. External sources of noise (random electromagnetic fluctuations) are examined and the conditions determined under which ultimate sensitivity is limited by noise generated in the receiver itself. The physical principles of emission and absorption of radiation are examined with particular reference to their application to the microwave region of the electromagnetic spectrum. The use of stimulated emission for amplification (maser action) is considered and various methods for its exploitation are discussed. Different types of maser amplifier are described and an elementary method of calculating their noise factors is given. Recent applications of maser amplifiers to radioastronomy and communications are described and some figures given to illustrate the large gain in ultimate sensitivity which has been obtained. Thus it is now possible to design an amplifier with noise equivalent to the input from a load at a temperature of only a few degrees K, and a whole system, including aerial and external noise from outer space, with noise equivalent to the input from a load at about 20° K.

7146 **EXPERIMENTAL VERIFICATION OF THE GAIN FORMULA FOR PARAMETRIC AMPLIFIERS.**

J.K.Buckley and J.J.Hupert.

Amer. J. Phys., Vol. 29, No. 5, 310-15 (May, 1961).

Recent developments in electronics strongly emphasize the theory and applications of parametric amplifiers. The derivation of the gain formula of a basic type of parametric amplifier is presented and an experiment described which quantitatively verifies this formula. In order to improve the accuracy of experimentation, the verifying tests are conducted at relatively low radio frequencies despite the fact that parametric amplifiers ordinarily find application at very high or microwave frequencies.

7147 **TRAVELING WAVE ANALYSIS OF A CLASS OF PARAMETRIC AMPLIFIERS BASED UPON THE HILL**

EQUATION. R.W.Fredricks.

J. appl. Phys. (USA), Vol. 32, No. 5, 901-4 (May, 1961).

A general travelling wave analysis is given for electron beam parametric amplifiers in which the electron dynamical equation in the pump is a Hill's differential equation. Formulas are given for the complex wave number of beam waves, and clear conditions for growing wave solutions are presented. The special case of a sinusoidal pump field variation is treated, and the optimum pumping condition is found to result when the pump frequency is twice the beam natural frequency. It is shown that growing wave solutions exist at pump frequencies which are rational fractions of the beam natural frequency, but that the growth constants for these pumping conditions (at fixed pump power) are orders of magnitude less than under the optimum condition.

**ANTIFERROMAGNETIC MATERIALS FOR MILLIMETRE AND SUBMILLIMETRE DEVICES.** See Abstr. 6381

7148 **DIFFRACTION OF ELECTROMAGNETIC WAVES AT RECTANGULAR APERTURES IN FLAT METAL**

SCREENS. H.Severin and K.Kürper.

Z. angew. Phys. (Germany), Vol. 13, No. 1, 41-7 (Jan., 1961). In German.

A known approximation technique enables the field distribution to be computed when the dimensions of the aperture exceed 2 or 3 wavelengths. It is found that the edges which are perpendicular to the E-vector of the incident field have little effect on the field structure.

V.G.Welsby

**DIFFRACTION BY AN IRREGULAR SCREEN OF LIMITED EXTENT.** See Abstr. 6962

**DIFFRACTION BY FINITE IRREGULAR OBJECTS.** See Abstr. 6963

7149 **HIGHER-ORDER EVALUATION OF DIPOLE MOMENTS OF A SMALL CIRCULAR DISK.** W.H.Eggmann.

IRE Trans Microwave Theory and Tech. (USA), Vol. MTT-8, No. 5, 573 (Sept., 1960).

Gives an expression correct to the sixth order in  $(ka)$  for the dipole moment of a conducting disk upon which a plane wave is normally incident. A third-order expression is given for the corresponding case of oblique incidence, ( $a$  is the disk radius and  $k = 2\pi/\lambda$ ).

G.D.Sims

7150 **A STUDY OF SURFACE ROUGHNESS AND ITS EFFECT ON THE BACKSCATTERING CROSS-SECTION OF SPHERES.** R.E.Hiatt, T.B.A.Senior and V.H.Weston.

Proc. Inst. Radio Engrs (USA), Vol. 48, No. 12, 2008-16 (Dec., 1960).

The effect on the scattering cross-section of a perfectly conducting object produced by surface roughness whose scale is only a small fraction of a wavelength is discussed. The object itself is assumed large compared with the wavelength. The roughness is assumed to be statistically random in nature and it is shown that this can be treated by means of an impedance boundary condition. This permits the use of known results to determine the resulting modification to the cross-section of the unperturbed object. Experimental data obtained by measuring the backscattering cross-section of a large rough sphere at three frequencies, S, X and K band, are presented. It is found that even for a sphere whose depth of roughness is as large as  $10^{-2}\lambda$ , the measured change in cross-section is no more than about 0.1 dB. This is in good agreement with the theoretical prediction.

**HIGHER ORDER-APPROXIMATIONS IN MULTIPLE SCATTERING.** See Abstr. 6934-5

**DIELECTRIC WAVEGUIDES AND AERIALS.**

7151 D.G.Kiely.

Progress in dielectrics. Vol. 3 (see Abstr. 5414 of 1961) p. 1-45.

A detailed survey of the theory and practice of dielectric rod and tube waveguides and aerials. 45 refs. J.B.Birks

**WAVEGUIDE EQUIPMENT FOR 2 mm MICROWAVES.**

7152 I. COMPONENTS.

C.W. van Es, M.Gevers and F.C. de Ronde.

Philips tech. Rev. (Netherlands), Vol. 22, No. 4, 113-125 (1960-61).

Description of a comprehensive range of waveguide components for measurements with 2 mm waves. The 2 mm waves are produced by using a point-contact diode to double the frequency of a DX 151 reflex klystron. Amongst the components discussed are a pivoting screws tuner (a variant of the sliding screw tuner), the p-i-n modulator (electrically controlled attenuator consisting of a germanium wafer with p, i, and n regions) a rotary attenuator (with direct reading), a hybrid Tee, a variable impedance (giving a direct reading of modulus and argument of the reflection coefficient), and a rotary directional coupler giving a direct reading of the coupling, which is continuously variable from -3 dB to -30 or -40 dB. Claw flanges make particularly compact assemblies possible.

**WAVEGUIDE EQUIPMENT FOR 2 mm MICROWAVES.**

7153 II. MEASURING SET-UPS.

C.W. van Es, M.Gevers and F.C. de Ronde.

Philips tech. Rev. (Netherlands), Vol. 22, No. 6, 181-9 (1960-61).

See preceding Abstr. Describes three measuring set-ups. The first one is for measuring the dissipative loss in microwave components, the second for measuring the reflection coefficient of impedances, and the third for determining absorption lines in gases. The gas carbonyl sulphide (COS), which exhibits an absorption line at about 146 Gc/s, is chosen as an example. Some 2 mm components which were not described in part 1 are also mentioned: a crystal detector, a waveguide switch and an isolator.

**PERTURBATION TECHNIQUES FOR MINIATURIZED COAXIAL Y-JUNCTION CIRCULATORS.**

7154 J.Clark.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 323S-324S (March, 1961).

Using theoretical synthesis procedures as a guide, systematic means were developed for constructing miniaturized coaxial Y-junction circulators at frequencies in C and X band. Subsequent investigation revealed that these techniques are useful at all frequencies down to the u.h.f. region. Maximum realization of the theoretical possibilities calls for techniques of symmetrically altering the junction that yield broad-range adjustment of the junction scattering matrix eigenvalues. Such techniques, involving dielectric loading and systematic deformation of the junction, are described. The device described, including permanent magnets, measures 1.5 in. in diameter, 0.75 in. in height, weighs less than 4 oz, and can easily be made to operate as a circulator at all frequencies from approximately 4 kMc/s to 10 kMc/s. Adjusted for use over the 5.4-5.9 kMc/s range, the circulator exhibits isolation greater than 20 dB, insertion loss less than 0.5 dB, and v.s.w.r. less than 1.3. These characteristics are maintained over a temperature range from -55°C to 110°C. At 5.65 kMc/s the circulator was operated satisfactorily at peak powers above 25 kW and average powers in excess of 25 W. No special cooling techniques were employed.

**PROJECT WEST FORD — PROPERTIES AND ANALYSES.**

INTRODUCTION. See Abstr. 6724

**PROPERTIES OF ORBITING DIPOLE BELTS.**

See Abstr. 6725

**RADIO PROPERTIES OF AN ORBITING SCATTERING**

MEDIUM. See Abstr. 6727

**ELECTROMAGNETIC RADIATION IN AN ATMOSPHERE OF ARBITRARY ELECTRIC CONDUCTIVITY.**

7155 F.Reiche and H.F.Ludloff.

Phys. of Fluids (USA), Vol. 4, No. 5, 618-21 (May, 1961).

The interaction of electromagnetic waves with an atmosphere of arbitrary electric conductivity  $\sigma$  is investigated, whereby  $\sigma$  is varied all the way from 0 to  $\infty$ . It is essential that the displacement current be taken into account. The generation of different kinds of hydromagnetic waves is analysed, and their phase velocity, polarization, and damping are derived as functions of two dimensionless parameters. Also, the relations between the amplitudes of the

electromagnetic and fluid vibrations are discussed. In the two limiting cases ( $\sigma = 0$  and  $\infty$ ), the general results coincide with the well-known formulae for a perfectly conducting gas and for a dielectric.

**MICROWAVE PROPAGATION THROUGH A MAGNETIC**

7156 PLASMA. R.L.Phillips, R.G.DeLosh and D.E.White.

J. appl. Phys. (USA), Vol. 32, No. 3, 551-2 (March, 1961).

This letter presents preliminary qualitative experience of the effect of a magnetic field of more than 17 000 gauss in the direction of propagation upon the attenuation and reflection of X-band microwave waves which were incident on a shock-tube plasma 1.5 cm thick. The microwave frequency was less than the plasma frequency and also less than the electron gyro-magnetic frequency when the magnetic field was on. The aim was to simulate radio communication metre wavelengths with a hypervelocity space vehicle through the self-generated envelope of plasma surrounding it. D.M.Gilbert

**SCATTERING OF ELECTROMAGNETIC WAVES IN THE**

7157 TROPOSPHERE AND THE USE OF THIS TECHNIQUE

FOR COMMUNICATIONS. I.H.Gerks.

Proc. Iowa Acad. Sci. (USA), Vol. 67, 399-430 (1960).

An introduction to the subject of tropospheric scatter propagation for the non-specialist. It opens with a review of various modes of propagation which may exist in a non-turbulent atmosphere such as diffraction and ionospheric reflection. The scattering of energy in a turbulent medium is then examined, and statistical methods are introduced to describe the resultant field. Special characteristics of the signal are discussed, such as variation with distance, climatic effects, frequency dependence, fading, bandwidth and noise level. The paper concludes with a description of methods and equipment employed in the design of a communication system operating over a distance in the range of 100 to 500 miles. It is concluded that tropospheric scatter terminals are large and costly but that under some circumstances such a system has economic advantages over a line-of-sight relay system and can furnish comparable quality and reliability.

**POLARIZATION CURVES FOR VERTICAL PROPAGATION OF RADIO WAVES IN THE IONOSPHERE.**

7158 Y.S.N.Murty and S.R.Khastgir.

J. sci. Industr. Res. (India), Vol. 19B, No. 8, 281-4 (Aug., 1960).

The curves giving the polarization angle  $\theta$  and the tilt angle  $\psi$  of the polarization ellipse for vertical sounding of the ionosphere with 100 m radio waves were drawn for the condition of the magnetic field in the ionosphere above Banaras (latitude 25°18'25" N; longitude 83°0'46" E; dip angle 36°26' N; and H 0.466 gauss). Three separate curves were drawn, one for each of the values of the electron collisional frequency,  $\nu = 0$ ,  $\nu = \nu_c/2$  and  $\nu = 2\nu_c$  (where  $\nu_c$  is the critical collisional frequency) with increasing values of the electron density which make the quantity  $4\pi Ne^2/m\omega^2$  vary from 0 to 2, where  $4\pi Ne^2/m\omega^2 = 1$  is the condition of reflection of the waves of the angular frequency  $\omega$ . In drawing these curves, use was made of the analytical expressions obtained earlier by the authors from the Appleton-Hartree formulae giving the ratio of the normal to the abnormal components of the magnetic vector of the wave (i.e. components in and at right angles to the plane containing the wave-normal and the direction of the magnetic field) and the phase-difference between them. The theoretical basis of the computation is given and the sign convention for representing the polarization parameters  $\theta$  and  $\psi$  is outlined. The nature of the variations in the polarization parameters, computed for increasing values of electron density, is discussed in detail.

STATISTICS OF A RADIO WAVE DIFFRACTED BY A RANDOM IONOSPHERE. See Abstr. 6607

## Radiofrequency Spectroscopy Techniques

**MEASUREMENT TECHNIQUE FOR NARROW LINE WIDTH FERROMAGNETS.**

7159 J.I.Masters, B.R.Capone and P.D.Gianino.

IRE Trans Microwave Theory and Tech. (USA), Vol. MTT-8, No. 5, 565-6 (Sept., 1960).

Describes a method for line width measurements of narrow line-width ferromagnetic samples. The sample is placed in a microwave field in a waveguide and a pick-up coil detects the precessing dipolar field of the sample. When the applied d.c. field is

near resonance a voltage is induced in the loop proportional to the microwave magnetic field. The line-width is found from measurements of the applied field and the microwave field at resonance. Results obtained using this method and a cavity perturbation method are compared.  
R.C.Glass

#### 7160 NUCLEAR RESONANCE MAGNETIC FIELD STABILIZER. R.G.Eades, G.J.Jenks and A.Bradbury.

J. sci. Instrum. (GB), Vol. 38, No. 5, 210-13 (May, 1961).

A nuclear resonance magnetic field stabilizer is described in detail. Circuit diagrams are included and the adjustment procedure is outlined for the particular application in which field fluctuations

of one part in  $10^3$  have to be handled. An improvement by a factor of 100 in field stability is readily obtained.

#### 7161 INCREASING THE INTENSITY OF $C^{13}$ N.M.R. SIGNALS BY A FLOWING SAMPLE METHOD.

S.Forsen and A.Rupprecht.

J. chem. Phys. (USA), Vol. 33, No. 6, 1888-9 (Dec., 1960).

An increase by a factor of three or four in the signal-to-noise ratio of the  $C^{13}$  resonance in benzene and in carbon tetrachloride, containing  $C^{13}$  in natural abundance, was achieved by causing the liquid to flow first through the polarizing field and then through the radiofrequency coil. The effect is due to the reduction of saturation by the constant supply of unsaturated material.  
E.F.W.Seymour

## NUCLEAR PHYSICS

#### 7162 THE ELEMENTS OF NUCLEAR PHYSICS [Eléments de physique nucléaire]. D.Blanc and G.Ambrosino.

Paris: Masson et Cie [1960] 238 pp. In French.

This is an introductory course for scientists and engineers who are not specialists in nuclear physics. The first chapters give a historical account of the structure of the atom, the nucleus and radioactivity. These are followed by chapters on nuclear reactions, the neutron, and nuclear fission. The last chapter deals with thermodynamic nuclear reactions and fusion reactors.

#### 7166 DELAY IN THE ONSET OF DISCHARGE IN LOW-VOLTAGE HALOGEN COUNTERS AS A FUNCTION OF TEMPERATURE. I.Zhelyazkov and M.Marinov.

C.R. Acad. Bulg. Sci., Vol. 12, No. 1, 17-20 (Jan.-Feb., 1959). In Russian.

The delay between the entry of an ionizing particle and the onset of discharge was measured. It is reported that at a working voltage of 400 V, the delay remains approximately constant at about  $3 \mu\text{sec}$  up to about  $25^\circ\text{C}$ . Between  $25$  and  $55^\circ\text{C}$  the delay is nearly doubled. These results were obtained for counters described as "Soviet STS-6 and MS-7 counters". No details of these counters are given.

S.Chomet

## APPARATUS PARTICLE DETECTORS

(Counting circuits are included under  
Electrical Measurements and Circuits)

#### 7163 THE USE OF THE NEON FLASH TUBE AS A DETECTOR OF IONISING PARTICLES. G.D.Rochester.

Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. II, p. 312-15.

The performance of a neon flash tube when used a particle detector is discussed in terms of the layer efficiency, which is the ratio of the number of simple flashes observed in a horizontal layer of tubes to the total number of particles passing through the layer in the same time interval, and the internal efficiency, which is the product of the layer efficiency and the ratio of the separation of the centres of two neighbouring tubes to the internal diameter of a tube. The dependence of the internal efficiency on neon pressure and its variation with the pulse parameters is given. The stability and lifetime of the tubes was examined. No significant change in the behaviour of the tubes was found in the temperature range  $14-40^\circ\text{C}$ . The lifetime of the tubes seems to be very long. The spatial resolution of the tubes is discussed.  
C.F.Barnaby

#### 7164 ON THE TEMPERATURE DEPENDENCE OF PULSE DEAD TIME IN HALOGEN COUNTERS.

L.G.Khristov and K.I.Kirov.

C.R. Acad. Bulg. Sci., Vol. 13, No. 4, 399-402 (July-Aug., 1960). In Russian.

The dead time in certain halogen-quenched Geiger counters was measured over a range of voltages and temperatures. The dead time was measured by comparison with the output pulse of an alcohol-quenched counter. The results support the view that dead time in a halogen-quenched counter is influenced by metastable atoms. It was found that over the normal working range a negligible variation of dead time occurred.  
A.E.I.Research Laboratory

#### 7165 A HIGH EFFICIENCY GEIGER MÜLLER COUNTER FOR MEASURING FLOWING RADIOACTIVE LIQUIDS.

F.Gadda and G.Redaeli.

Energia nucleare (Italy), Vol. 7, No. 10, 701-4 (Oct., 1960).

Details of the unusual construction are reported. The counter is filled with a neon-argon mixture, using bromine as quenching agent; it shows quite good working characteristics. The efficiency of the counter for various  $\beta$ -emitters with maximum energy ranging from 0.3 to 2.2 MeV was plotted. At the highest energy experimented with (using  $Y^{90}$  where  $E_{\text{max}} = 2.21 \text{ MeV}$ ) an efficiency greater than 50% was obtainable.

#### $2\pi$ PROPORTIONAL COUNTER SPECTROMETER: PROPERTIES AND USE IN DISINTEGRATION RATE MEASUREMENTS. See Abstr. 7353

#### 7167 DIFFERENTIAL IONIZATION CHAMBER FOR THE MEASUREMENT OF THE ACTIVITY OF RADIOACTIVE GASES. J.Marvaud.

Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 183-91. In French.

The collectors of two chambers operated with h.t. supplies of opposite polarity are connected together. One chamber receives the radioactive gas while the other receives only the ambient radiation. The common collector current represents the difference between the total activity and that of the gas.  
W.G.Stripp

#### 7168 DISCRIMINATION OF PULSE SHAPE WITH A MINERAL SCINTILLATOR (CsI). APPLICATION TO THE PLOTTING OF $\alpha$ -SPECTRA OR OF PROTON SPECTRA IN THE PRESENCE OF $\gamma$ -RAYS.

F.Cambou, J.P.Crettez and G.Ambrosino.

C.R. Acad. Sci. (France), Vol. 251, No. 23, 2681-3 (Dec. 5, 1960). In French.

The shape of the luminous scintillation pulse, produced by ionizing particles in CsI, is different for protons,  $\alpha$ -particles and electrons. A discriminator circuit was constructed utilizing this property and allowing the suppression of the  $\gamma$ -background during measurements on proton or  $\alpha$ -particle spectra. Oscillograms of output pulses are shown for: (a)  $\text{Na}^{22} \gamma$ -rays, (b)  $\text{Pu} \alpha$ -particles, and (c)  $\alpha + \gamma$ . The spectrum of recoil protons due to 3 MeV neutrons, and that of  $\alpha$ -particles in the presence of  $\text{Na}^{22} \gamma$ -rays are also presented.  
I.C.Demetsopoulos

#### 7169 THE SPECIFIC FLUORESCENCE OF PLASTIC SCINTILLATOR NE102. J.R.Prescott and A.S.Rupaal.

Canad. J. Phys., Vol. 39, No. 1, 221-7 (Jan., 1961).

The value of  $kB$  in Birks' formula for the specific fluorescence of an organic scintillator

$$\frac{dS}{dx} = \frac{A (dE/dx)}{1 + kB (dE/dx)}$$

was evaluated for specimens of plastic scintillator NE102 of different age, by comparing the response to gamma-rays and alpha-particles. For 7 specimens manufactured between 1958 and 1960, an average value of  $kB = 9.21 \pm 0.17 \text{ cm air equivalent MeV}^{-1}$  ( $= 0.0098 \pm 0.0008 \text{ g cm}^{-2} \text{ MeV}^{-1}$ ) was obtained. (One early

1958 specimen had  $kB = 12.9$  cm air equivalent  $\text{MeV}^{-1}$ . Using recoil protons a value of  $kB = 0.0091 \pm 0.0006$   $\text{g cm}^{-2} \text{MeV}^{-1}$  was obtained for a typical specimen. This latter value is considered more reliable.

J.B.Birks

# 7170 SCINTILLATION COUNTING WITH ORGANIC PHOSPHORS. B.L.Funt.

Canad. J. Chem., Vol. 39, No. 3, 711-16 (March, 1961).

Current techniques employed in scintillation detection of beta emitters are reviewed. Internal liquid scintillation counting, with a number of homogeneous mixed solvent systems, is described. Heterogeneous counting systems containing radioactive material in the dispersed phase include scintillating gels, thickened scintillators, and emulsions, and a number of methods embodying direct counting of active deposits on filter paper. Heterogeneous systems with the radioactive material in the continuous phase are described and include plastic capillary counters, plastic filaments, or organic crystals wetted with aqueous solutions.

# 7171 STATISTICAL LIMITS IN TIMING WITH SLOW SCINTILLATORS. F.T.Arecchi, A.De Matteis and E.Gatti.

Energia nucleare (Italy), Vol. 7, No. 10, 697-700 (Oct., 1960).

With reference to previous work (see Abstr. 8679 of 1957, 17139 of 1960) on timing with scintillation counters, results on variances in time measurements are extended to the case of slow scintillators, e.g.  $\text{NaI(Tl)}$ , for two different methods of timing. The systematic dependence of machine time on the amplitude of the scintillation (the so-called "machine time walk") also is given.

# 7172 UTILIZATION OF OPTICAL FILTERS IN A SCINTILLATION DETECTOR. E.Boldt and C.Tsipis.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 280-1 (March, 1961).

The detector described consists of a block scintillator covered by a  $4\pi$  anticoincidence shield of scintillation plastic sheets. By means of optical filters, the light emitted by the shield is distinguished from the light arising from the core scintillator.

# 7173 ITERATIVE RESPONSE CORRECTION FOR A SCINTILLATION SPECTROMETER.

L.D.Skarsgard, H.E.Johns and L.E.S.Green.

Radiation Research (USA), Vol. 14, No. 3, 261-80 (March, 1961).

A system has been established which facilitates rapid correction of extensive data on radiation spectra, measured with a  $\text{NaI:Tl}$  scintillation crystal. It employs a simple iterative procedure and a consistent criterion for the selection of a "best" approximation. A preliminary test for the convergence of the iterations has been developed, and considerable experimental evidence is given for the validity of the solution. The methods are particularly suitable for use with an automatic computer. The response of the detector has been measured experimentally and is represented by a single forty-ninth order matrix. The energy range may be altered simply by substituting a different response matrix in the correction programme.

# 7174 ON A VELOCITY DISCRIMINATOR, WHICH USES THE CHERENKOV EFFECT.

J.C.Dumas, C.Mabboux and R.Moch.

C.R. Acad. Sci. (France), Vol. 252, No. 4, 547-9 (Jan. 23, 1961). In French.

Describes preliminary results using two gas Cherenkov counters in anticoincidence. By arranging the thresholds of the two counters to be slightly different, velocity discrimination may be obtained.

R.H.Thomas

# 7175 THE HANDLING OF DATA FROM NUCLEAR EXPERIMENTS. H.I.Pizer.

Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 215-21.

Recent developments in sorting, recording and analysing apparatus for counter experiments are reviewed. Methods of plotting coordinates of tracks are described; these include a servo-operated track follower which enables coordinates to be recorded on punched tape.

W.G.Stripp

# 7176 THE INTEREST OF MAGNETIC STORAGE IN NUCLEAR PHYSICS. A.Pages.

Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 283-90. In French.

Pulses to be analysed are converted to trains of pulses up to 63 in number and these are written in on a 6-track tape for later read-out and analysis.

W.G.Stripp

## Track Visualization

### 7177 VELOCITY DEPENDENCE OF TRACK DENSITY IN PROPANE AND HYDROGEN BUBBLE CHAMBERS.

A.Ahmadzadeh and N.N.Biswas.

Nuovo Cimento (Italy), Vol. 19, No. 5, 958-70 (March, 1961).

A study of ionization data for charged particles was made in an underexpanded propane and a normally operated hydrogen bubble chamber. The gap-length distribution was found to be exponential over a wide range of velocity intervals and the coefficient of this distribution gives a measure of the true track density  $g$ ;  $g$  is proportional to  $\beta^{-n}$ , where  $n = 1.71 \pm 0.11$  for propane and  $n = 1.86 \pm 0.37$  for hydrogen. The density of gaps,  $G$ , or of blobs,  $B$ , defined with good objective criteria, shows a dependence on  $g$ , namely  $G(\epsilon) = g \exp[-g(\alpha + \epsilon)]$ ; it passes through a maximum value, the position of which is related to the minimum resolvable gap distance (approximately the average diameter of individual bubbles). The mechanisms of energy loss or  $\delta$ -ray formation for the process of bubble nucleation are discussed in view of these measurements. The track density  $g$  was found to be approximately proportional to the rate of energy loss,  $dE/dX$ ; this would indicate that the bubble nucleation process may not be as simple as has been considered so far.

### 7178 THE DEVELOPMENT OF THE PHOTOGRAPHIC METHOD OF RECORDING TRACKS OF NUCLEAR PARTICLES. C.F.Powell.

Austral. J. Sci., Vol. 23, No. 4, 105-8 (Oct., 1960).

Review article.

### 7179 DETERMINATION OF THE SENSITIVITY OF EMULSIONS PREPARED BY THE BROMINATION OF A SILVER HYDROSOL. M.Morand, J.C.Fayolle and S.Desprez-Rebe.

C.R. Acad. Sci. (France), Vol. 252, No. 4, 542-3 (Jan. 23, 1961). In French.

The sensitivity of emulsions prepared by the bromination of silver hydrosols is found to lie in the region of 6 to 7 keV, a value slightly below that of Ilford C2 emulsion.

S.J.St-Lora

### 7180 THE DEVELOPMENT OF NUCLEAR EMULSIONS. L.M.Barkov and D.M.Samoilovich.

Dokl. Akad. Nauk SSSR, Vol. 136, No. 5, 1059-62 (Feb. 11, 1961). In Russian.

The fine-grain fog occurring in the prolonged development of nuclear emulsions is explained, on a simple statistical basis, as the development of un-ionized microcrystals of the emulsion. The discussion is extended to give a qualitative account of the weak dependence on development time of the grain density of tracks of relativistic particles in terms of the fluctuations arising in the ionization process and the fluctuations in the number of traps in a microcrystal. [English translation in: Soviet Physics-Doklady (USA)].

J.E.Gol

### 7181 METHODS OF IMPROVEMENT OF THE QUALITY OF DEVELOPMENT OF THICK LAYERS OF EMULSION (400 MK). M.Nikolae.

Rev. de Physique (Roumania), Vol. 5, No. 2, 229-38 (1960). In Russian.

Experiments are described which study the effect of varying the conditions of development of glass-mounted emulsions, on three properties of the developed emulsion relevant to physics, namely the evenness of development versus depth from surface to base, grain density at minimum ionization, and grain density of background haze. New methods of development are described, one of which optimizes the evenness of development. The other optimizes all three properties, and in comparison with the usual method, improves them by 8%, 14%, and 20%, respectively.

D.W.L.Sprun

### OBSERVATION OF HIGH-ENERGY JET SHOWERS AND HIGH-ENERGY $\gamma$ -RAYS BY MEANS OF LARGE EMULSION CHAMBERS. See Abstr. 7296

### 7182 DETAILS OF THE CONSTRUCTION OF SCINTILLATION CHAMBERS. J.Duflou.

J. Phys. Radium (France), Vol. 21, Suppl. No. 3, 65A-68A (March, 1960). In French.

The system utilizes refrigerated CsI filaments and a Lallemand-Duchesne electronic camera. The angular distribution

of the light emitted by the filaments was studied and remarks are made concerning possible optical systems for transmitting the light from scintillator to camera.

IMAGE INTENSIFIERS FOR NUCLEAR TRACK IMAGING.  
See Abstr. 7090

## NUCLEAR FIELD THEORY

INTRODUCTION TO QUANTUM MECHANICS. See  
Abstr. 6779

7183 FIELD METRICS. II. A CORRECTION.  
P.Sen.  
Nuovo Cimento (Italy), Vol. 18, No. 3, 613 (Nov. 1, 1960).  
See Abstr. 15224 of 1960.

7184 ON THE CONNECTION OF SPIN AND COMMUTATION  
RELATIONS BETWEEN DIFFERENT FIELDS. H.Araki.  
J. math. Phys. (USA), Vol. 2, No. 3, 267-70 (May-June, 1961).

The connection of spin and commutation relations for different fields is studied. The normal locality is defined as the property that two Boson fields as well as a Boson field and a fermion field commute, while the two fermion fields anticommute with each other at a spacelike distance. A regular locality is defined as any combination of commutativity and anticommutativity between various pairs of fields at spacelike distance, where the kinematically related fields are assumed to obey the same type of commutation relations. The normal and regular weak locality is defined in a corresponding way. It is proved on the basis of the Lorentz invariance and spectrum conditions that any regular locality is equivalent to the normal locality plus a set of even-oddness conservation laws. It is further shown, under the assumption of the normal weak locality between pairs of the same field, that any regular weak locality is equivalent to the normal weak locality plus a set of even-oddness conservation laws.

7185 THE EQUATIONS OF MOTION OF CLASSICAL  
CHARGES. F.Rohrlich.  
Ann. Phys. (USA), Vol. 13, No. 1, 93-109 (April, 1961).  
The problem of the physical solutions of the Dirac equation for classical charges is not the usual initial value problem of Newtonian dynamics where the motion is determined by initial position and velocity. Asymptotic conditions must simultaneously be fulfilled. This undesirable feature is eliminated if one uses a set of integro-differential equations of second order as the basic equations of motion. These are equivalent to the Dirac equation together with the asymptotic conditions, and pose a Newtonian initial value problem with no further conditions. The "principle of undetectability of small charges" which states that in the limit  $\epsilon \rightarrow 0$  the motion of a charged particle must approach the motion of a neutral particle of the same mass can be shown to be valid on the basis of these equations, a fact which is not generally valid for the solutions of the Dirac equations. A successive approximation procedure is developed valid for a large class of external forces. The "noninstant" character of the new equations is discussed and is shown to be observable in principle. But causality is not violated within the domain of validity of classical electrodynamics. One obtains a consistent theory which can have physical solutions in agreement with experiments for all nonquantum mechanical problems.

7186 FREE QUANTIZED LORENTZIAN FIELDS.  
J.Schwartz.  
J. math. Phys. (USA), Vol. 2, No. 3, 271-90 (May-June, 1961).  
A systematic classification is made of all local Lorentz-invariant quantized field theories which are free in the sense that  $[\psi(x), \psi(x)]$  is a c number. It is shown that none exist except those given in the classical paper of Fierz (Abstr. 938 of 1939), and that, in fact, certain of the fields listed by Fierz are redundant.

7187 REMARKS ON A PAPER BY BIALYNICKI-BIRULA ON  
SOME PROPERTIES OF GREEN'S FUNCTIONS.  
E.R.Caianiello.  
Nuovo Cimento (Italy), Vol. 18, No. 6, 1291-2 (Dec. 16, 1960).  
Brief comment on Bialynicki-Birula's paper. No results are given. See Abstr. 20017 of 1960.

7188 ON RADIATIVE CORRECTIONS DUE TO SOFT  
PHOTONS. K.E.Eriksson.

Nuovo Cimento (Italy), Vol. 19, No. 5, 1010-28 (March 1, 1961).

It is shown how the infrared divergent part, due to soft virtual photons, of any scattering amplitude can be factorized in a Lorentz invariant manner. It is further shown that if the energy resolution for a process is negligible compared to the electron rest mass then the whole soft photon contribution to the transition probability density can be factorized leaving a Lorentz-invariant remainder. This factorization is then extended to the more realistic case of an energy resolution which is of the same order of magnitude as the electron rest mass, or larger. Finally, the magnitudes of radiative corrections are discussed.

7189 INCONSISTENCY OF THE LOCAL FIELD THEORY OF  
CHARGED SPIN  $\frac{1}{2}$  PARTICLES.

K.Johnson and E.C.G.Sudarshan.  
Ann. Phys. (USA), Vol. 13, No. 1, 126-45 (April, 1961).

The relativistic quantum theory of Fermi-Dirac fields of arbitrary spin is investigated and a general theorem is proved which asserts that for fields of half integral spin  $> \frac{1}{2}$ , the possibility of a consistent quantization requires that the equal-time anticommutators must be functions of the other fields to which the field in question is coupled. The case of spin  $\frac{3}{2}$  is studied in detail and the equivalence of various formulations of the theory is shown. The inconsistency of the relativistic local quantum theory of a charged spin  $\frac{3}{2}$  field in interaction with an external electromagnetic field is demonstrated by showing that the equal time commutation relations and relativistic covariance of the theory are not compatible. Finally, the mixed spin  $\frac{3}{2}$ -spin  $\frac{1}{2}$  (Bhabha) field is found to be characterized by the same inconsistency.

7190 SPINOR FIELDS IN SPACES WITH TORSION.  
R.Finkelstein.

Ann. Phys. (USA), Vol. 12, No. 2, 200-21 (Feb., 1961).

It is suggested that the short-range interactions lead to a torsion of physical space, as gravitational interactions lead to its curvature. The existence of torsion implies two kinds of parallelism, (+) and (-), which in turn imply two types of spinor field,  $\psi(+)$  and  $\psi(-)$ . If the geometry is symmetric with respect to (+) and (-) parallelisms, then  $\psi(+)$  and  $\psi(-)$  have no vector or electromagnetic coupling, and the geometry may be called neutral. The simplest neutral geometry with variable torsion is derivable from a Lagrangian in which a pseudoscalar Yukawa field (the torsion potential) is coupled by pseudovector coupling to  $\psi(+)$  and  $\psi(-)$ . If the geometry does not have neutral symmetry, then  $\psi(+)$  and  $\psi(-)$  behave like a charge doublet. The hypercharge and the parity of this charge doublet are determined by the weight of the spinor under general coordinate transformations. It follows from the model that leptonic ( $m = 0$ ) particles are not coupled to the torsion.

7191 CALCULATION OF THE FERMION MASS IN NON-  
LINEAR SPINOR THEORY. Arif-Uz-Zaman.

Z. Naturforsch. (Germany), Vol. 16a, No. 3, 225-7 (March, 1961).  
In German.

The contraction function  $\langle 0 | T \psi_\alpha(x) \psi_\beta(x') | 0 \rangle$  occurring in the nonlinear spinor theory of Heisenberg is approximated by assuming that the density function  $\varrho(x)$  contains a normal particle state at  $\xi = x^2$  and a dipole ghost at  $\xi = m^2$ . This assumption is slightly more general than that in the original paper, where the mass of the dipole ghost was taken as  $\xi = 0$ . The intention of the present calculation was to see whether the approximation could be improved in this way and whether a certain inconsistency mentioned in the earlier paper would disappear. The nucleon mass value  $m_N$  is calculated in the lowest approximation of the Tamm-Dancoff method. It is shown that only for  $m^2/x^2$  less than about 0.05 real values of  $m_N$  are obtained, i.e. the dipole ghost has to be assumed at zero mass or very near to it. The inconsistency of the method mentioned in earlier work still persists.

7192 NOTE ON DIRAC METHOD OF LINEARISING THE  
RELATIVISTIC HAMILTONIAN. K.C.Kar.

Indian J. theor. Phys., Vol. 7, No. 3-4, 53-5 (Sept.-Dec., 1959).

It is pointed out that the conditions of the method are ignored in its subsequent use. It is also shown that all the Dirac results can be obtained if unit vectors are introduced instead of matrices.

7193 DYNAMICAL MODEL OF ELEMENTARY PARTICLES  
BASED ON AN ANALOGY WITH SUPERCONDUCT-  
IVITY. I. Y.Nambu and G.Jona-Lasinio.  
Phys. Rev. (USA), Vol. 122, No. 1, 345 (April 1, 1961).

It is suggested that the nucleon mass arises largely as a self-

energy of some primary fermion field through the same mechanism as the appearance of energy gap in the theory of superconductivity. The idea can be put into a mathematical formulation utilizing a generalized Hartree-Fock approximation which regards real nucleons as quasi-particle excitations. A simplified model of non-linear four-fermion interaction is considered which allows a  $\gamma_5$ -gauge group. An interesting consequence of the symmetry is that there arise automatically pseudoscalar zero-mass bound states of the nucleon-antinucleon pair which may be regarded as an idealized pion. In addition, massive bound states of nucleon number zero and two are predicted in a simple approximation. The theory contains two parameters which can be explicitly related to observed nucleon mass and the pion-nucleon coupling constant. Some paradoxical aspects of the theory in connection with the  $\gamma_5$  transformation are discussed in detail.

**7194 INTERACTIONS BETWEEN MATTER AND RADIATION IN FUNCTIONAL THEORY.** Pham Xuân Yêm.  
J. Phys. Radium (France), Vol. 21, No. 3, 185-8 (March, 1960).  
In French.

Interactions between an electron and many photons are expressed by the terms of coupling in the equations of those two types of particles: the action of the electron is represented in the electromagnetic equations of the photons in terms of electric and magnetic moments and in charge and current densities. Conversely, the potentials created by the photons will react upon the movement of the electron.

**7195 WEAK INTERACTIONS [Interazione deboli].**  
Rendiconti della Scuola Internazionale di Fisica  
"Enrico Fermi", Corso XI. Bologna: Zanichelli (1960) 406 pp.  
Papers presented at the summer school at Varenna, Italy,  
June 29-July 11, 1959. Abstracts will appear in this or subsequent  
numbers of "Physics Abstracts" under their appropriate headings.

**7196 RESONANCE REACTIONS AND CONTINUOUS CHANNELS.** L. Fonda.  
Ann. Phys. (USA), Vol. 12, No. 3, 476-84 (March, 1961).  
A general formal theory of resonance reactions is extended to the case in which continuous channels are present. The introduction of continuous channels does not alter the formal results and interpretation for the resonances which appear in two-particle  $\rightarrow$  two-particle reactions. Breit-Wigner formulae are obtained for a type of resonance which occurs under certain conditions in reactions leading to three-body channels as a function of the momentum of one of the particles while the total energy is fixed.

**7197 RENORMALIZATION OF A STRONG NUCLEON, HYPERON, K-MESON INTERACTION WHICH DOES NOT CONSERVE PARITY.** R. Nataf.  
J. Phys. Radium (France), Vol. 21, No. 3, 174-84 (March, 1960).  
In French.

The consequences of such an interaction as suggested by Soloviev (Abstr. 2761-2 of 1958) are investigated (PC invariance being assumed). Second order corrections for dressed particles (propagators, vertex operators, etc.) are calculated, and it is found that the  $\Sigma$  dressed field has a mixed parity with respect to the nucleon dressed field. This result is eliminated by renormalization, performed for all orders, carried out nearly in the same way as d'Espagnat and Prentki (Abstr. 880 of 1958), some of the relations being however different.

**7198 STUDY OF A MODEL FIELD WITH ZERO RENORMALIZATION CONSTANT.** J.C. Houard and B. Jouvét.  
Nuovo Cimento (Italy), Vol. 18, No. 3, 466-81 (Nov. 1, 1960).  
In French.

It is shown for a soluble example that a theory with Fermi coupling is equivalent to a theory with Yukawa coupling in which the renormalization constant of the intermediate particle is zero. The singularity of the commutation relations is examined. The zero nature of the renormalization constant is interpreted in a Lagrangian formalism as a constraint imposed on the fields. J.E. Paton

**7199 STATISTICAL THEORY OF MULTIPLE PARTICLE PRODUCTION WITH ANGULAR MOMENTUM CONSERVATION.** Z. Koba.

Nuovo Cimento (Italy), Vol. 18, No. 3, 608-12 (Nov. 1, 1960).  
A new formulation of Fermi's statistical theory of multiple particle production is discussed in which the condition of the angular momentum conservation is fulfilled and which can thus be applied to the analysis of peripheral collisions and angular distribution of secondary particles. J.H. Gunn

**7200 RELATIVISTIC PARTICLE SYSTEMS WITH INTERACTION.** L.L. Foldy.  
Phys. Rev. (USA), Vol. 122, No. 1, 275-88 (April 1, 1961).  
The possibility of covariantly describing a system of a fixed number of particles interacting directly is explored by attempting a direct "integration" of the commutation relations for the inhomogeneous Lorentz group under restrictions appropriate to the term "system of a fixed number of particles". By direct interaction is meant the fact that interaction between the particles is expressed directly in terms of coordinates, momenta, and spins for the particles rather than through the agency of a mediating field. The integration is carried out in considerable generality with the assumption that the infinitesimal generators of the group have expansions in inverse powers of the square of the velocity of light. The result coincides with that obtained earlier by Bakamjian and Thomas (Abstr. 3058 of 1954), but the method employed yields greater insight into the generality of the result, as well as into how further conditions beyond covariance, such as the property which is here called "separability of the interaction", can be incorporated in the result. The relationship of the result to the complete reducibility of a representation of the inhomogeneous Lorentz group is pointed out. Possible generalizations and applications of the procedures here employed are discussed.

**7201 INTERNAL SYMMETRIES OF STRONG BARYON-MESON INTERACTIONS.** Y. Shimamoto.  
Phys. Rev. (USA), Vol. 122, No. 1, 289-97 (April 1, 1961).  
A simple model considered previously by Pais (Abstr. 3704 of 1958), in which the  $\Sigma$  and  $\Lambda$  hyperons are regarded as a mass-degenerate supermultiplet in the strong pion interaction, is reconsidered. It is shown that recognition of the symmetry exhibited by these hyperons in their pionic coupling leads to certain prescriptions which may be used to break the symmetry via the strong K-meson interactions. The symmetry reduction schemes described make possible the construction of a strong baryon-meson interaction Hamiltonian which requires no more than four coupling constants (rather than the customary eight) and which in no way imposes severe restrictions on the strong interactions. Finally, production and scattering amplitudes based on the 4-symmetry are discussed.

**7202 TIME-ORDERED GREEN'S FUNCTIONS AND ELECTROMAGNETIC INTERACTIONS.** K. Nishijima.  
Phys. Rev. (USA), Vol. 122, No. 1, 298-306 (April 1, 1961).  
For previous work, see Abstr. 15300 of 1960. Various aspects of the Ward-Takahashi equations are studied. In perturbation theory the equivalence between this set of equations and the requirement of gauge invariance is shown. It is shown that these equations are valid for composite particles as well as for elementary particles. Based on this new formulation a definition of composite particles is given, and it is shown with the aid of the Ward-Takahashi equations that the photon is an elementary particle.

**7203 TIME-ORDERED GREEN'S FUNCTIONS AND PERTURBATION THEORY.**  
M. Muraskin and K. Nishijima.  
Phys. Rev. (USA), Vol. 122, No. 1, 331-40 (April 1, 1961).  
A formulation of field theories based on the generalized unitarity condition and parametric dispersion relations is presented. In the perturbation theory the authors discuss the connection between the present scheme and the Lagrangian theory and derive the renormalizability condition in the present formulation. Finally it is shown that typical processes in the first, second, third and fourth orders that this theory can reproduce the renormalized Feynman perturbation theory.

**7204 V- $\theta$  COLLISIONS IN THE LEE MODEL.** R.D. Amado.  
Phys. Rev. (USA), Vol. 122, No. 2, 696-704 (April 15, 1961).  
The methods of dispersion theory are used to obtain an exact expression for the V- $\theta$  elastic scattering amplitude and the amplitude and the amplitude for the production process,  $V + \theta \rightarrow N + 2\theta$ , in the Lee model (Abstr. 9936 of 1954).

**7205 COUPLED INTEGRAL EQUATIONS OF THE OMNES-MUSKHELISHVILI TYPE.** S.W. MacDowell.  
Phys. Rev. Letters (USA), Vol. 6, No. 7, 385-7 (April 1, 1961).  
The Omnes method of solving certain singular integral equations (Abstr. 3630 of 1958) is extended to coupled equations that arise in many-channel  $\gamma$  reactions. R.J.N. Phillips

- 7206 TWO-PARAMETER APPROXIMATION TO S-WAVE SCATTERING.** D.M.Greenberger and B.Margolis. Phys. Rev. Letters (USA), Vol. 6, No. 6, 310-11 (March 15, 1961).  
**ERRATUM.** *ibid.*, No. 8, 428 (April 15, 1961).  
 A simple two-parameter approximation to scattering amplitudes calculated from the Mandelstam representation is put forward which is claimed to be more accurate than the usual simple pole approximation. The technique is illustrated for the singlet S-wave nucleon-nucleon amplitude. J.H.Gunn
- 7207 POSSIBLE RELATIONS AMONG THE MESON-BARYON COUPLING CONSTANTS.** D.B.Lichtenberg. Ann. Phys. (USA), Vol. 12, No. 2, 264-82 (Feb., 1961).  
 It is assumed that the strong interactions of the mesons and baryons can be described in terms of a Lagrangian containing at most eight coupling constants. A simple assumption is then made that only one magnitude  $g$  is required to describe all the pion-baryon couplings and that one magnitude  $f$  is sufficient to describe the couplings of the baryons to K-mesons. Within this restriction, there are  $3^8 = 6561$  ways to write down the Lagrangian, since each of the eight coupling constants may be positive, negative, or absent. It is shown that many of these possibilities lead to equivalent descriptions of the strong interactions, and that still other possibilities lead to predictions in contradiction to experiment. However, several hundred nonequivalent Lagrangians satisfying the assumptions are not eliminated by the arguments of this paper. Examination of a number of the remaining possibilities in fourth-order perturbation theory indicates that some of them are more likely than others, but none can be ruled out by the arguments given here.
- 7208 LOW-ENERGY PREDICTIONS OF MODIFIED YUKAWA POTENTIALS BETWEEN TWO NUCLEONS.** D.B.Lichtenberg. Amer. J. Phys., Vol. 29, No. 6, 357-64 (June, 1961).  
 Predictions of the Yukawa potential are reviewed. It is pointed out that the potential leads to qualitative, but not quantitative, agreement with two-nucleon experiments at low energy. The agreement can be made quantitative by making modifications of the Yukawa potential at internucleon separations smaller than  $\frac{1}{2}$  the Compton wavelength of the  $\pi$  meson. This result is illustrated with specific examples of modified potentials. The significance of these potentials is discussed.
- 7209 ANGULAR DISTRIBUTION IN MULTIPLE PROCESSES.** B.T.Vavilov. Dokl. Akad. Nauk SSSR, Vol. 137, No. 1, 51-3 (March 1, 1961). In Russian.  
 An initial state consisting of  $i$  bosons,  $n$  fermions and  $k$  anti-fermions is postulated, and the matrix operator  $V_{ij,nm,k}^{l_1,l_2}$  for the transition  $i \rightarrow j$ ,  $m \rightarrow n$ ,  $k \rightarrow l$  is formulated. For the multiple production of pions by collision of two high-energy nucleons the anisotropy of the pion distribution can be evaluated from  $V_{ij,nm,k}^{l_1,l_2}$  fairly readily as the summation over states reduces to a few terms. [English translation in: Soviet Physics-Doklady (USA)]. J.W.Gardner
- 7210 NOTE ON THE WAVESTATISTICAL DERIVATION OF KLEIN-NISHINA FORMULA FOR COMPTON SCATTERING.** K.C.Kar and B.N.Paria. Indian J. theor. Phys., Vol. 7, No. 3-4, 56-60 (Sept.-Dec., 1959).  
 The theory and the mechanism of the different processes involved are critically discussed.
- 7211 ON THE DISTINGUISHABILITY OF EQUIVALENT POTENTIALS.** M.A.Baqi Bég. Ann. Phys. (USA), Vol. 13, No. 1, 110-25 (April, 1961).  
 The possibility is explored of discriminating between equivalent potentials (i.e. potentials reproducing the same phase shifts and bound state energies for the two-body problem) by making use of three-body amplitudes. Working with a simple model of a two-body target and making approximations characteristic of a high-energy treatment, it is found that the three-body amplitude can be decomposed into two parts; one sensitive to the nature of the two-body force, the other expressible in terms of two-body observables. When the two-body interaction terminates exactly beyond a certain distance  $a$ , the first part arises entirely from the overlap of the target particles if they are regarded as spheres of radius  $a$ . By consideration of effective range theory a brief discussion is given of potentials with infinitely long tails. For such interactions the second part of the composite amplitude is always zero. In order to

avoid extensive digressions into the problem of potential construction (for potentials belonging to assigned classes) the discussion is restricted to the two classes for which this problem has been solved, namely, local and nonlocal separable potentials.

- 7212 A PROOF OF THE MANDELSTAM REPRESENTATION IN PERTURBATION THEORY.** P.V.Landshoff, J.C.Polkinghorne and J.C.Taylor. Nuovo Cimento (Italy), Vol. 19, No. 5, 939-52 (March 1, 1961).  
 The Mandelstam representation is proved in each finite order in perturbation theory for processes for which forward scattering dispersion relations have been proved. A continuation in the external masses is then made so that the proof is extended to all processes for which there is no anomalous threshold in lowest order.
- 7213 MANDELSTAM REPRESENTATION WITH ANOMALOUS THRESHOLDS.** R.J.Eden, P.V.Landshoff, J.C.Polkinghorne and J.C.Taylor. Phys. Rev. (USA), Vol. 122, No. 1, 307-12 (April 1, 1961).  
 It is proved that fourth-order diagrams provide necessary and sufficient conditions for the Mandelstam representation (Abstr. 1256 of 1960) to be valid for every finite order in perturbation theory.
- 7214 HIGH-ENERGY BEHAVIOUR OF ELECTROMAGNETIC SCATTERING CROSS-SECTIONS.** K.E.Eriksson. Nuovo Cimento (Italy), Vol. 19, No. 5, 1044-52 (March 1, 1961).  
 The theory of the renormalization group is used in order to show that for large momentum transfer the perturbation expansion in  $\alpha$  of the differential cross-section for the scattering of an electron by a potential in first order Born approximation is expanded in terms of the effective parameter  $(\alpha/\pi) \ln(q^2/m^2)$ . ( $q$  = invariant momentum transfer,  $m$  = electron rest mass;  $q/m \gg 1$ ).
- 7215 HIGH-ENERGY POTENTIAL SCATTERING WITH SHORT-RANGE FORCES.** B.J.Malenka and H.S.Valk. Phys. Rev. (USA), Vol. 122, No. 3, 931-3 (May 1, 1961).  
 An attempt is made to separate out long- and short-range effects for high-energy elastic scattering. Within the context of a high-energy approximation, expressions for the scattering amplitudes are obtained for the cases  $kR \gg ka \gg 1$  and  $kR \gg 1 > ka$ , where  $R$  and  $a$  denote the long and short ranges, respectively. For the latter case, the entire short-range effect is included in a phenomenological S-wave term while the long-range contributions are written explicitly.
- 7216 CONSTRUCTION OF UNITARY SCATTERING AMPLITUDES.** R.Blankenbecler. Phys. Rev. (USA), Vol. 122, No. 3, 983-92 (May 1, 1961).  
 A general linear technique is discussed which constructs unitary scattering amplitudes without expanding in partial waves and in the presence of inelastic channels. Two- and three-particle intermediate states are discussed explicitly, but the method can be extended directly to any finite number of particles. A new approximation technique suggested by this formalism is applied to electroproduction of pions from pions and pion-K-meson scattering. A form of the impulse approximation is derived for both the coupled scattering amplitude problems. The nucleon and deuteron form factor system is briefly discussed. Finally, a model field theory which contains three-particle intermediate states is formulated and solved by the linear technique for purely pedagogical reasons.
- 7217 FORM OF THE ONE-PION EXCHANGE POTENTIAL.** G.Breit, M.H.Hull, Jr, K.Lassila and H.M.Ruppel. Phys. Rev. Letters (USA), Vol. 5, No. 6, 274-6 (Sept. 15, 1960).  
 A test is made of the mathematical form of the OPEP, by including extra terms and varying their strength and the value of the  $\pi$ -N coupling constant to obtain the best statistical fit to the N-N data. The test indicates the absence of large deviations from the OPEP. The method might in the future give evidence on the two-pion contribution. J.E.Paton
- 7218 KINEMATICAL AND DYNAMICAL RESONANCES.** A.O.Barut and K.H.Ruei. Phys. Rev. (USA), Vol. 122, No. 4, 1340-2 (May 15, 1961).  
 A method is given to distinguish between the solutions of the dispersion relations corresponding to kinematical and dynamical resonances. It consists of studying the resonance energy as a function of the coupling constant. The method is illustrated for potential scattering, for charged scalar meson theory, and for resonances due to unstable particles.

**7219 WAVE EQUATIONS INVARIANT UNDER DISCONTINUOUS GROUPS AND THE PROBLEM OF NUCLEAR FORCES.** P.G.O.Freund.  
Acta phys. Polon. (Poland), Vol. 19, No. 2, 139-48 (1960).  
It is shown that physical space has only the role of a representation-space of a certain group. In a consequently discontinuous theory, space-time, therefore, may be left topological but the fundamental group is to be taken as discontinuous. A two-dimensional theory of nuclear forces invariant only under a discontinuous rotation group is developed. Hence an angular periodicity of the nuclear forces results. Three- and four-dimensional generalizations lead to the non-Euclidian space and space-time and thus may serve as physical support of Einstein's gravitation theory. It is shown that theories invariant under discontinuous groups do not contain conservation laws.

**7220 ON THE PERTURBATION THEORY WITH TIME-DEPENDENT WAVE FUNCTIONS.** K.C.Kar.  
Indian J. theor. Phys., Vol. 7, No. 3-4, 65-72 (Sept.-Dec., 1959).  
The perturbation formula used in radiation problems is derived from an entirely wave statistical point of view.

**7221 BARYCENTRE IN FUNCTIONAL THEORY OF PARTICLE SYSTEMS.** F.Aeschlimann.  
J. Phys. Radium (France), Vol. 21, No. 2, 115-20 (Feb., 1960). In French.  
Definition of the barycentric wave for a system of  $n$  particles in the functional theory is discussed, in the relativistic case and in the non-relativistic case with spin and isospin or without spin. Equations for the barycentric wave in the relativistic case and in the non-relativistic case, and the case of particles of the same mass are dealt with as are motion around the barycentre, equations for the relative motion, and the special case of a two-particle system.

**7222 APPROACH TO EQUILIBRIUM OF A LARGE FERMION SYSTEM.** K.Nishikawa.  
J. Phys. Soc. Japan, Vol. 15, No. 1, 78-92 (Jan., 1960).  
Using Feynman diagrams, the dissipative behaviour of a large quantum system of many fermions is discussed. On the basis of linked cluster expansion of the time-dependent perturbation theory, the master equation is derived for a time sufficiently long compared with the effective collision time and for a slowly varying initial distribution in the momentum space. Van Hove's result for the weak-coupling limit and the equation for the low-density limit are obtained as special cases.

source-detector geometries: barrier geometry (source and detector on either side of the absorber), half-barrier geometry (source in a semi-infinite medium, detector outside the medium), and infinite geometry (source and detector within an infinite medium). The sources used were  $\text{Au}^{198}$  ( $E_\gamma = 0.411$  MeV),  $\text{Cs}^{137}$  ( $E_\gamma = 0.661$  MeV),  $\text{Zn}^{65}$  ( $E_\gamma = 1.12$  MeV) and  $\text{Na}^{24}$  ( $E_\gamma = 1.38$  and  $2.76$  MeV), water being used as absorber. The  $\gamma$ -ray build-up factors are greatest for an infinite and least for a barrier geometry, the difference increasing with decreasing  $E_\gamma$ . I.C.Demetsoyopoulou.

**7226 INTERACTION OF GAMMA RADIATION WITH MATTER.** V.Lakshminarayana and S.Jnanananda.  
J. sci. industr. Res. (India), Vol. 20B, No. 1, 1-7 (Jan., 1961).  
Total atomic cross-sections for gamma-rays from  $\text{Co}^{60}$ ,  $\text{Sc}^{46}$ ,  $\text{Cs}^{134}$ ,  $\text{Cs}^{137}$ ,  $\text{Cr}^{51}$  and  $\text{Ce}^{141}$  in the elements carbon, aluminium, copper, tungsten and lead were determined with a modified narrow-beam geometry, using a scintillation detector of good figure of merit. Theoretical cross-sections were computed and compared with experimental results. Good agreement is observed for light elements at energies greater than 662 keV. Deviations are observed for light elements at lower energies and for heavy elements at all energies. In the case of light elements, the deviations are ascribed to the errors in theoretical evaluation of scattering cross-sections.

**7227 PLASTIC SCINTILLATORS IN DOSIMETRY OF INTENSE  $\gamma$  RADIATION BEAMS.** R.D.Lonati and G.Skoff.  
Energia nucleare (Italy), Vol. 8, No. 3, 188-95 (March, 1961).  
To determine the isodose curves in materials subject to a beam of intense gamma radiations, the light generated in a plastic scintillator is used. The plastic is photographed, and from the blackening produced in the various points of the film, the dose absorbed in the corresponding points of the plastic is calculated.

**7228 A THEORY OF BREMSSTRAHLUNG FROM NON-RELATIVISTIC ELECTRONS.** V.V.Babikov.  
"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 309-21.  
Corrections are obtained to the main terms of the Born and quasi-classical approximations for the spectral distribution of bremsstrahlung produced by electrons in a Coulomb field.

## ELEMENTARY PARTICLES

**7223 ARE THERE SOME NEW FUNDAMENTAL PARTICLES?** A.Salam.  
Pakistan J. Sci., Vol. 12, No. 4, 166-70 (July, 1960).  
Review for the non-specialist of the properties of the neutrino, with an outline of the dualon hypothesis.

**RESONANCE REACTIONS AND CONTINUOUS CHANNELS.**  
See Abstr. 7196

## Photons

**7224 EXTENSION OF THE METHOD OF QUASI-REAL PROCESSES TO BOSON-PHOTON INTERACTIONS.** P.Kessler.  
C.R. Acad. Sci. (France), Vol. 252, No. 9, 1279-1281 (Feb. 27, 1961). In French.  
See Abstr. 20021 of 1960. The method gives a formula for the process  $\gamma + p \rightarrow p + \pi^- + \pi^+$  practically identical with that of Drell (Abstr. 20095 of 1960). J.E.Paton

**7225 THE EFFECT OF BOUNDARY CONDITIONS ON THE  $\gamma$ -RAY BUILD-UP FACTOR.** V.M.Kodiukov.  
Atomnaya Energiya (USSR), Vol. 6, 673 (1959). In Russian. English translation in: Reactor Science (GB), Vol. 12, No. 4, 217-19 (Aug., 1960).

A comparison is made of the  $\gamma$ -ray build-up factor, defined as the ratio of the attenuation uncorrected for multiple scattering to that when such scattering is allowed for, obtained with the following

## Electrons

**7229 DETERMINATION OF ELECTRON AND POSITRON HELICITY WITH MÖLLER AND BHABHA SCATTERING.** J.D.Ullman, H.Frauenfelder, H.J.Lipkin and A.Rossi.  
Phys. Rev. (USA), Vol. 122, No. 2, 536-48 (April 15, 1961).  
The determination of the helicity of electrons and positrons from beta decay by means of electron-electron (Moller) and positron-electron (Bhabha) scattering is discussed. The theoretical background, the apparatus, and the experimental procedure are treated in detail. The apparatus included, in addition to the conventional parts, a beta monochromator with a momentum resolution of 16% for the investigation of the energy dependence of the helicity. Experiments were performed with  $\text{P}^{32}$ ,  $\text{Au}^{198}$ ,  $\text{RaE}(\text{Bi}^{210})$  and  $\text{Ga}^{68}$ . In all cases, the helicities  $P$  were found to be proportional to  $v/c$ . The measured helicities, in units of  $v/c$  and averaged over the observed range of energies, are summarized as follows, (the errors given are statistical only; systematic errors are estimated to be less than  $\pm 3\%$ ):

| Radioisotope                  | Particles | Energy interval<br>in keV | Helicity<br>$P/(v/c)$ |
|-------------------------------|-----------|---------------------------|-----------------------|
| $\text{P}^{32}$               | $e^-$     | 660 - 990                 | $-1.00 \pm 0.02$      |
| $\text{Au}^{198}$             | $e^-$     | 460 - 810                 | $-0.98 \pm 0.03$      |
| $\text{RaE}(\text{Bi}^{210})$ | $e^-$     | 520 - 950                 | $-0.75 \pm 0.03$      |
| $\text{Ga}^{68}$              | $e^+$     | 1030, 1300                | $+0.99 \pm 0.09$      |

**ELECTRON SCATTERING ON PROTONS AND DEUTERONS: INTERPRETATION BY NUCLEON CHARGE-CORE MODEL.** See Abstr. 7232

**MOTT POLARIZATION IN SCATTERING OF ELECTRONS FROM THOMAS-FERMI AND HARTREE ATOMS.** See Abstr. 5978

# 7230 APPLICATION OF THE METHOD OF REAL QUASI-PROCESSES TO INTERNAL PAIR PRODUCTION.

P.Kessler.  
C.R. Acad. Sci. (France), Vol. 252, No. 7, 994-6 (Feb. 13, 1961).  
In French.

The phenomenon of internal pairs is treated by the method of quasi-real processes, particularly in the decay of the uncharged pion and in the capture of the negative pion in hydrogen. J.H.Gunn

# 7231 PAIR PRODUCTION BY MEANS OF SLOW CHARGED PARTICLES IN THE COULOMB FIELD. E.Hara.

Z.Naturforsch. (Germany), Vol. 16a, No. 2, 155-61 (Feb., 1961). In German.

The pair production cross-section for heavy particles in the Coulomb field is calculated using Schrödinger—Coulomb wave-functions for the heavy incident particles and plane waves for the created pair. It is shown that the order of magnitude of the cross-section thus obtained is given by the product of the value deduced by Heitler and Nordheim (Abstr. 4871 of 1934) in the Born approximation, and the Sommerfeld correction factor, which is known for the emission of bremsstrahlung. The total cross-section is computed for proton energies of 8 m c<sup>2</sup>, 12 m c<sup>2</sup> and 16 m c<sup>2</sup>. It turns out to be smaller than the result of Heitler and Nordheim by several orders of magnitude.

# THE EFFECT OF TEMPERATURE ON THE ANGULAR CORRELATION OF $\gamma$ -RAYS EMITTED DURING ELECTRON—POSITRON ANNIHILATION IN BISMUTH. See Abstr. 6095

## Nucleons

# 7232 ELECTROMAGNETIC PROPERTIES OF THE PROTON AND NEUTRON.

D.N.Olson, H.F.Schopper and R.R.Wilson.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 286-90 (March 15, 1961).

New measurements of electron—proton and electron—deuteron scattering up to  $q^2 = 35 \text{ fermi}^{-2}$  are interpreted in terms of a charge core model of the nucleon.  $F_{2S}$  is assumed zero.  $F_{1V}$  has no core.  $F_{1S}$  then has a core of radius  $0.2 \pm 0.1 \text{ fermi}$  and charge  $0.35 e$ . The remaining  $F_{1S}$  is a gaussian or exponential cloud, charge  $0.15 e$ , radius  $1.4 \pm 0.4 \text{ fermi}$ . The neutron charge distribution has a positive tail beyond 1.5 fermis. D.W.L.Sprung

# 7233 DIRAC AND PAULI FORM FACTORS OF THE NEUTRON. R.Hofstadter, C.de Vries and R.Herman.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 290-3 (March 15, 1961).

Measurements of electron—proton and electron—deuteron scattering up to  $q^2 = 20 \text{ fermi}^{-2}$  are used to deduce the neutron form factors  $F_{1N}$ ,  $F_{2N}$  by the method of intersecting ellipses. The reasonable set is chosen. D.W.L.Sprung

# 7234 ELECTRIC AND MAGNETIC STRUCTURE OF THE PROTON AND NEUTRON. R.Hofstadter and R.Herman.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 293-6 (March 15, 1961).

The form factors of the previous abstract are interpreted by fitting Clementel—Villi form factor shapes. In coordinate space this gives Yukawa shape charge distributions with delta-function cores. The cores for proton and neutron have 0.12 and 0.32 charges respectively. The neutron charge distribution has a positive tail beyond 1.6 fermis. D.W.L.Sprung

# 7235 EFFECTS OF K-MESON INTERACTIONS ON THE NUCLEON ANOMALOUS MAGNETIC MOMENT.

K.Nishimura.

Phys. Rev. (USA), Vol. 122, No. 1, 312-16 (April 1, 1961).

A previous calculation (Abstr. 9229 of 1959) of the physical nucleon wave-function in static-source pion theory is extended by including the pseudoscalar K-meson interactions, the motivation being that this should increase the scalar part of the nucleon anomalous magnetic moment, thus improving the result of the previous calculations. In constructing a trial function for the physical nucleon, the method of moments was used and terms containing up to three mesons were included. Calculation shows that a too strong K-meson coupling is detrimental to the vector part, and that the scalar part can be increased approximately by 10% if the K-meson interaction is made moderately low.

# CHARGED-SCALAR STRONG-COUPPLING THEORY FOR

## 7236 TWO-NUCLEON SYSTEM. K.W.Chun.

Phys. Rev. (USA), Vol. 122, No. 3, 973-83 (May 1, 1961).

The Serber—Pais charged-scalar strong-coupling method (Abstr. 3970 of 1957) is extended to the two-nucleon system. It is shown explicitly that whereas the nuclear force depends on the renormalized coupling constant alone at the large internucleon separations, its dependence on the unrenormalized coupling constant alone becomes increasingly pronounced as the two nucleons come closer together.

# S-WAVE NUCLEON-NUCLEON SCATTERING: TWO-PARAMETER APPROXIMATION. See Abstr. 7206

## Protons

# 7237 THE PROTON AS A FUNDAMENTAL PARTICLE.

S.M.Ayub.

Pakistan J. Sci., Vol. 12, No. 4, 184-6 (July, 1960).

Review for the non-specialist.

# 7238 NUCLEAR INTERACTIONS OF PROTONS, NEUTRONS, AND SHOWER PARTICLES OF VERY HIGH ENERGY IN NUCLEAR EMULSION. A.G.Barkow, B.Chamany, D.M.Haskin, P.L.Jain, E.Lohrmann, M.W.Teucher and M.Schein.

Phys. Rev. (USA), Vol. 122, No. 2, 617-25 (April 15, 1961).

Eighty-four interactions of protons and neutrons were located in a 22 litre stack of nuclear emulsion by tracing back showers of minimum-ionizing particles to their origins. The distribution of the number of shower particles, and the number of heavily ionizing prongs, are presented for 57 events with dip angles  $< 17^\circ$ . The average energy of these events is  $3.5 \times 10^{12} \text{ eV}$ . The average number of shower particles emitted in nucleon—nucleon collisions at this energy is  $15 \pm 5$ , as estimated from 8 interactions without heavy prongs. The angular distributions of the shower particles are presented for the 57 events. They can be transformed into a system in which the angular distribution is roughly symmetric. This is true even for the collisions with heavy target nuclei ( $N_h > 5$ ). The degree of anisotropy of the angular distributions is in disagreement with a hydrodynamical model of nucleon—nucleus collisions. A lower limit for the collision mean free path of the primary particles of 20 cm in emulsion was obtained. By scanning the forward cone of the primary interactions, 76 secondary interactions of charged and neutral shower particles were found. The distribution of the prong numbers, of the energy, and the characteristics of their angular distribution are presented. The best estimate of the ratio of secondary collisions produced by neutral particles, and the number produced by charged particles is:  $N_n/N_{ch} = 0.40 \pm 0.11$ . Adding this result to other published data, it is concluded that  $30 \pm 6\%$  of the particles produced in collisions having a primary energy of several TeV are not  $\pi$ -mesons. A collision mean free path of  $41 \pm 8 \text{ cm}$  was found for the forward-cone shower particles. See also following abstract.

# 7239 ANGULAR DISTRIBUTIONS OF SECONDARY PARTICLES PRODUCED IN HIGH-ENERGY NUCLEAR COLLISIONS AND THE TWO-CENTER MODEL OF MULTIPLE MESON PRODUCTION. J.Gierula, D.M.Haskin and E.Lohrmann.

Phys. Rev. (USA), Vol. 122, No. 2, 626-36 (April 15, 1961).

The angular distributions of shower particles from 54 nuclear interactions of protons and neutrons with energies  $> 10^{12} \text{ eV}$  in a stack of nuclear emulsions are analysed. The method consists essentially in normalizing the angular distributions of all events in the  $x = \log \tan \theta$  scale to the same dispersion  $\sigma$ . One finds a very significant deviation from the normal distribution predicted by hydrodynamical models. The deviation goes in the direction indicated by the two centre model (two maxima in the plot over the  $x$ -coordinate). The correlation between the separation of the two emitting centres and  $\sigma$  is also in qualitative agreement with the model. The angular distribution in the rest system of the emitting centres is found to be roughly isotropic. The two-centre model also offers an explanation for certain characteristic features observed for the angular distribution of events with a small number of shower particles ( $n_g \leq 5$ ). On the basis of this model a coefficient of inelasticity of  $\approx 0.2$  is obtained for these events. Interactions characterized by small evaporation ( $N_h \leq 5$ ) and small numbers of shower particles ( $n_g \leq 20$ ) show the characteristic two-maximum shape. The same shape is found for, presumably central, collisions with heavy nuclei in the emulsion ( $N_h > 8$ ,  $n_g > 40$ ). However, the

group of collisions with  $N_h \leq 5$ ,  $n_s > 20$  does not show the two maxima. The last two observations cannot be explained by the present simple form of the two-centre model. The results of this paper are in good agreement with a similar analysis carried out by Gierula, Miesowicz, and Zielinski (Abstr. 20271, 20306 of 1960).

7240 NUCLEAR INTERACTIONS AND MEAN FREE PATHS OF PROTONS, NEUTRONS, AND ALPHA PARTICLES AT ENERGIES AROUND 250 BeV/NUCLEON.

E.Lohrmann, M.W.Teucher and M.Schein.  
Phys. Rev. (USA), Vol. 122, No. 2, 672-86 (April 15, 1961).

Nuclear interactions of protons, neutrons,  $\alpha$ -particles, and heavier nuclei of average energy 250 BeV/nuc were studied in nuclear emulsion. The source of these particles were fragmentations of heavy primary nuclei of the cosmic radiation. Their energy was determined from multiple scattering measurements. The interaction mean free path for protons is  $41 \pm 10$  cm, for  $\alpha$ -particles  $27 \pm 7$  cm. The mean free path shows no significant change compared with measurements at lower energies. The mean number of shower particles  $\langle n_s \rangle$  depends appreciably on the mass of the target nucleus. The authors' best estimate for nucleon-nucleon collisions at 250 BeV is  $\langle n_s \rangle = 8.8 \pm 1.9$ . A detailed comparison of the estimate of the primary energy obtained from the angular distribution of shower particles with the true primary energy is carried out. The angular distribution of the shower particles will, in an individual case, give a quite unreliable value for the primary energy. In the average, the angular distribution method will overestimate the true primary energy by a factor of 1.3 for interactions with a number of heavy prongs  $N_h \leq 5$ . If  $N_h > 5$ , the angular distribution will underestimate the true energy in the average by a factor of 1.8. The angular distributions can be transformed into a system in which they are symmetric. This is even true for collisions with heavy target nuclei ( $N_h > 5$ ). The results for  $\alpha$ -particle and heavy nucleus collisions are quite similar. The inelasticity for the proton and neutron interactions shows large fluctuations for individual events. It depends weakly on the number of shower particles and on the mass of the target nucleus. Its mean value is 50%. The mean value for the  $\alpha$ -particle collisions is 22%.

7241 ELASTIC SCATTERING OF 14 MeV PROTONS BY DEUTERONS AND BY PROTONS. S.Kikuchi, J.Sanada, S.Suwa, I.Hayashi, K.Nisimura and K.Fukunaga.

J. Phys. Soc. Japan, Vol. 15, No. 1, 9-17 (Jan., 1960).

The differential cross-sections for the elastic scattering of 13.93 MeV protons by deuterons were measured with an accuracy varying from 1 to 3% at angles from  $12^\circ$  to  $164^\circ$  in the centre-of-mass system. A shallow Coulomb-nuclear interference minimum near  $17^\circ$  was observed. The angular distribution is in good agreement with that of neutrons scattered by deuterons at 14 MeV, although the p-d cross-sections seem systematically a little smaller than the n-d cross-sections at backward angles. For forward angles, the experimental results contradict the predictions of the existing theory. The small-angle p-d elastic scattering at 10.14 MeV was investigated and a similar shallow Coulomb-nuclear interference was observed, in contrast to the theoretical curve of Christian and Gammel. The p-p scattering experiment at 14.16 MeV is also described. Measurements were made with an accuracy of 1 to 2% for angles from  $30^\circ$  to  $114^\circ$  in the centre-of-mass system.

7242 BREMSSTRAHLUNG IN p-p-COLLISIONS AT AN ENERGY OF 150 MeV. C.Dullemond and J.J.de Swart.

Physica (Netherlands), Vol. 26, No. 8, 664-8 (Aug., 1960).

The differential cross-section for bremsstrahlung in p-p collisions at an energy of 150 MeV is calculated at the upper end of the photon spectrum. The only transition which is considered is the E2 transition between  $^1D_2$  and the  $^3S_0$  state. The Siegert theorem is used and the influence of the Coulomb force between the two protons is neglected.

7243 ELASTIC AND QUASI-ELASTIC COLLISIONS OF PROTONS WITH MOMENTUM BETWEEN 9 AND 25 GeV/c.

G.Cocconi, A.N.Diddens, E.Lillethun and A.M.Wetherell.  
Phys. Rev. Letters (USA), Vol. 6, No. 5, 231-4 (March 1, 1961).

Using the internal circulating beam of the CERN 25 GeV proton synchrotron, a beryllium target was bombarded at 9 different values of the circulating beam momentum. Momentum spectra of the positive particles emitted at 60 mrad to the beam are given which show, in all but the highest momentum cases, a double peaked behaviour. The authors conclude that the particles detected in the

peaks and in the continuum are protons and that they are produced in the interaction of the primary protons with the single nucleons of the beryllium nuclei.

J.H.Gun

7244 RANGE OF PROTON-ANTIPROTON ANNIHILATION NEAR 1.0 BeV. O.Hara.

Phys. Rev. (USA), Vol. 122, No. 2, 669-71 (April 15, 1961).

The range of the annihilation is calculated, the objective being the range of the pure annihilation interaction, separating the effects of pion production. It was found that the root mean square of this range is given by  $(1.19 \pm 0.07) \times 10^{-13}$  cm almost independently of the energy.

## Neutrons

7245 ORIGIN OF THE WORD "NEUTRON". S.G.Brush.

Nature (GB), Vol. 190, 251-2 (April 15, 1961).

The word has been attributed to Rutherford and to Harkins but was probably not used by either before 1920. The writer refers to a paper by Sutherland [Phil. Mag. (GB), (Sixth Ser.), Vol. 3, 162 1902] in which a neutron is defined as an electron doublet of + and - electrons.

NEUTRON FORM FACTORS. See Abstr. 7233

7246 THE DISTRIBUTION OF INTENSITY OF NEUTRON RADIATION ALONG THE AXIS OF A STRAIGHT TUBE DURING A STRONG PULSED DISCHARGE IN DEUTERIUM.

N.A.Borzunov and D.V.Orlinski.

"Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 223-38.

The experimental work is described briefly. Curves are given for the dependence of the neutron radiation on the original voltage and on the deuterium pressure.

7247 NEUTRON-PROTON SCATTERING AND THE DETERMINATION OF THE PION-NUCLEON COUPLING CONSTANT. R.R.Larsen.

Nuovo Cimento (Italy), Vol. 18, No. 5, 1039-42 (Dec. 1, 1960).

The n-p differential charge-exchange cross-section was measured at 9 angles between  $160^\circ$  and  $180^\circ$  c.m., to an accuracy of 5%. An attempt was made to determine the pion-nucleon coupling constant by extrapolation to the one pion exchange pole. A modified extrapolation method gave the value  $f^2 = 0.085 \pm 0.011$ .

D.W.L.Sprue

THE POLARIZATION OF NEUTRONS FROM THE  $Li^7(p, n)Be^7$  REACTION. See Abstr. 5911-12

7248 THE UNIT OF NEUTRON FLUX. I.

I.S.McGill, D.C.Menzies and M.R.Price.

Nature (GB), Vol. 190, 162 (April 8, 1961).

Supports the idea of a new unit (Abstr. 509 of 1961) but suggests that a more practical definition would be 1 chad  $\equiv 10^{12}$  neutrons  $cm^{-2} sec^{-1}$ . The flux in most power reactors is of the order  $10^{12}$  and this definition would thus avoid the use of large powers of 10.

7249 A REMARK ON THE TRANSPORT MEAN FREE PATH OF THERMAL NEUTRONS IN GRAPHITE.

M.Kuchle and K.H.Beckurts.

Reactor Science (GB), Vol. 10, No. 3-4, 157-8 (Sept., 1959).

Values are quoted for the transport mean free path in graphite for different samples using the pulsed neutron source method. Some discrepancy is observed between the samples which is unexplained.

J.F.Hill

7250 THE VALUE OF TRANSPORT MEAN FREE PATH FOR  $D_2O$ . D.W.Hone.

Reactor Science (GB), Vol. 11, No. 1, 34 (Nov., 1959).

The data of the only value of the transport mean free path in heavy water, reported by Auger, Munn and Pontecorvo (see Abstr. 2980 of 1947), have been re-analysed assuming that the asymptotic neutron distribution was (1) a straight line, (2) a sinh curve. The analysis confirmed that the original account assumed a straight line, arriving at a value of 2.40 cm. The value arrived at from the sinh fit was  $2.60 \pm 0.10$  cm.

J.F.Hill

7251 ON THE PASSAGE OF SLOW NEUTRONS THROUGH A CRYSTAL PLATE. A.A.Atanassov.

C.R. Acad. Bulg. Sci., Vol. 13, No. 5, 527-30 (Sept.-Oct., 1960).

The problem of the passage of slow neutrons through a crystal

plate is considered. The influence of secondary diffused waves is dealt with by a method analogous to that used in the consideration of the passage of electromagnetic waves through a crystal plate. The crystal considered is rhombic with one atom in each of its cells and a condition is derived for the diffraction of neutrons falling normally onto the crystal plate.

J.F.Hill

7252 CHEMICAL BINDING EFFECTS IN THE THERMALIZATION OF NEUTRONS. N.Corngold. *Ann. Phys. (USA)*, Vol. 11, No. 3, 338-58 (Nov., 1960).

In an earlier paper (Abstr. 8463 of 1959) an asymptotic series solution in half-integral powers of  $(kT/E)$  was extracted from the Boltzmann transport equation for neutrons coming into thermal equilibrium with a moderating material. This paper considers the series in detail for moderators having simple crystalline structure, or in which vibrational modes predominate, and give the coefficients of the series explicitly in terms of moments of the frequency spectrum of crystal vibrations. Calculations indicate that the neutron density in the asymptotic region increases as the spectrum of crystal vibrations hardens, whence the "hardness" of the neutron spectrum increases too. Some aspects of the mass-expansion for these systems are discussed and the calculations compared with those of other workers, and with typical experimental data for thermalization in water. Finally, the asymptotic expansion for moments of the scattering kernel and for  $\xi\sigma_s$ , the slowing down power, are discussed.

DOPPLER EFFECT IN NEUTRON ABSORPTION RESONANCES. See Abstr. 5919

7253 ON SOME INTERCOMPARISONS BETWEEN CALIBRATED NEUTRON SOURCES.

G.P.Felcher, E.Germagnoli, M.Musci and G.Poletti.

Energia nucleare (Italy), Vol. 8, No. 2, 105-6 (Feb., 1961).

A short report is given of the intercalibration measurements which were performed with the CISE Ra  $\alpha$  + Be neutron source.

7254 OPTICAL CHARACTERISTICS OF A MECHANICAL NEUTRON MONOCHROMATOR WITH HELICAL SLOTS.

Bally, E.Tarină and P.Pirlogea.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 297-303 (March, 1961).

The expression of the function  $f(\lambda)$  defining the transmission of a mechanical monochromator with helical slots when the incident neutron beam is limited by a Soller collimator has been calculated. The influence of the total reflection from the collimator walls upon the function  $f(\lambda)$  was also studied. The paper describes a mechanical monochromator with helical slots devised for the suppression of the higher-order Bragg reflections from a crystal. Measurements with this monochromator have served to check the calculations.

CONSTRUCTION OF A CHRONOTRON FOR MEASUREMENT OF FLIGHT TIME OF FAST NEUTRONS. See Abstr. 7011

AUTOMATIC APPARATUS FOR MEASURING LOCAL GRADIENTS OF NEUTRON FLUX. See Abstr. 5955

7255 NEUTRON TEMPERATURE MEASUREMENTS WITH  $^{176}\text{Lu}$ . G.A.Price.

Reactor Science (GB), Vol. 10, No. 3-4, 157 (Sept., 1959).

A method is described for measuring neutron temperatures between 18°C and 99°C using the  $\text{Lu}^{176}(n, \gamma)$  reaction. It is shown that the reaction is potentially capable of measuring the neutron temperature in this range to about 5°C.

C.F.Barnaby

## Mesons

7256 RADIATIVE CORRECTIONS TO MUON-ELECTRON SCATTERING. K.E.Eriksson.

Nuovo Cimento (Italy), Vol. 19, No. 5, 1029-43 (March 1, 1961).

The differential cross-section for  $\mu$ -e scattering is calculated to order  $e^6$ .

7257 SCATTERING OF 2 BeV/c MUONS IN CARBON AND LEAD.

G.E.Masek, L.D.Heggie, Y.B.Kim and R.W.Williams.

Phys. Rev. (USA), Vol. 122, No. 3, 937-48 (May 1, 1961).

The scattering cross-section of high-energy  $\mu$ -mesons in carbon and lead was measured, using a pure, monoenergetic beam of muons obtained with the Bevatron at the Lawrence Radiation Laboratory. Preparation, purification, and measured properties of the

beam are described. The median momentum was  $2.00 \pm 0.03$  BeV/c, the spread in momentum was not more than  $\pm 3.5\%$ , and the effective contamination due to pions was  $4.9 \times 10^{-6}$ . During the experiment the total number of muons incident on the apparatus was  $2.5 \times 10^7$ . Counter hodoscopes recorded the muons scattered from  $14.4 \text{ g/cm}^2$  of lead and from  $27 \text{ g/cm}^2$  of carbon. Inelastic as well as elastic processes were accepted. Scattered particles were observed at angles up to  $12^\circ$  (momentum transfer  $\sim 400 \text{ MeV/c}$ ). The lead data cover the same range as those cosmic-ray experiments which have appeared to indicate an anomalously large scattering. No anomaly is found; the lead scattering agrees closely with the distribution calculated by Cooper and Rainwater for purely electromagnetic interactions. The carbon data permit a better comparison with theoretical expectations, since one is measuring the single-scattering cross-section directly, and one can account for the effects of nuclear structure rather accurately, using electron-scattering data and a detailed theoretical analysis of Drell and Schwartz. The carbon scattering results, based on 300 events in the region 70-400 MeV/c momentum transfer, agree closely with the Drell-Schwartz theory. The upper limits which this result places on a nonelectromagnetic scattering cross-section and on a muon form factor are discussed.

7258 MULTIPLE SCATTERING OF  $\mu$ -MESONS IN LEAD.

L.B.Bishara, Noor El Din Abd El Aziz and S.R.Haddara.

Proc. Math. Phys. Soc. Egypt, No. 22, 121-30 (June, 1958).

A cloud chamber was used for the investigation of multiple scattering of  $\mu$ -mesons in lead. Data obtained from 358 events are analysed and the experimental distribution is compared with the theories of Williams (1939), Moliere (1943, 1948) and Olbert (1953, 1958). It is shown that the present results agree more with the Moliere distribution in which a point charge nucleus is assumed. Probable processes other than Coulomb scattering are discussed.

7259 LARGE ANGLE SCATTERING OF  $\mu$ -MESONS.

L.B.Bishara, Noor El-Din Abd Aziz and S.R.Haddara.

Proc. Math. Phys. Soc. Egypt, No. 22, 131-5 (June, 1958).

The integral distribution of large angle scattering of  $\mu$ -mesons in a multiplate cloud chamber is obtained. Large angles are taken as angles greater than 3 times the root mean square of the angles of scattering. The distribution is compared with the theoretical distribution proposed by Olbert (1952, 1953) for effective radii of atomic nuclei 0.05, 0.7, and  $1 R_N$ , where  $R_N$  is the geometrical radius of the nucleus. The distribution fits fairly well with a point charge nucleus. A cross-section for anomalous scattering of about  $12 \times 10^{-28} \text{ cm}^2/\text{nucleon}$  is obtained.

7260 NUCLEAR CAPTURE OF NEGATIVE MUONS WITH ELECTRON EMISSION.

M.Conversi, L.di Lella, A.Egidi, C.Rubbia and M.Toller.

Nuovo Cimento (Italy), Vol. 19, No. 5, 987-98 (March 1, 1961). In Italian.

An experimental search for neutrinoless  $\mu^-$  capture with electron emission is described.  $\mu^-$ -mesons from the CERN 600 MeV synchrocyclotron were made to stop in a copper target. The upper limit for the branching ratio of the process sought, relative to ordinary muon capture, has been improved by more than a factor 20 with respect to the most sensitive previous measurements.

INVESTIGATION OF THE PROCESS  $\mu^- + N = e^- + N$ .

7261 M.Conversi, L.di Lella, A.Egidi, C.Rubbia and M.Toller.

Nuovo Cimento (Italy), Vol. 19, No. 5, 999-1009 (March 1, 1961). In Italian.

This was studied making use of the low-energy high-intensity  $\mu^-$  beam recently developed at CERN. If, as expected on theoretical ground, coherent neutrinoless capture of muons in copper is at least 6 times more probable than the corresponding incoherent process, the branching ratio relative to ordinary muon capture turns out to be less than  $5.9 \times 10^{-6}$ , with 90% confidence level. This result is compared with that independently obtained in an experiment of similar sensitivity carried out at the Berkeley synchrocyclotron.

SEARCH FOR A NEUTRAL MESON OF ZERO I-SPIN.

7262 N.E.Booth, O.Chamberlain and E.H.Rogers.

Nuovo Cimento (Italy), Vol. 19, No. 5, 853-63 (March 1, 1961).

A search was made for a neutral meson of zero isotopic-spin by means of the reaction  $d + d \rightarrow \text{He}^4 + \pi^0$ . No evidence was found for the existence of the  $\pi^0$  in the mass range zero to 1.8 times the  $\pi^\pm$  mass. The upper limit of the cross-section was  $7 \times 10^{-32} \text{ cm}^2$  for  $\pi^0 \cong \pi^\pm$  mass. The reaction was studied by using 460 MeV deuterons from the Berkeley 184 in. cyclotron and a liquid deuterium target.  $\alpha$ -particles produced at  $0^\circ$  in the laboratory system

were selected by momentum analysis and by a counter telescope which measured time of flight,  $dE/dx$ , and differential range. The experiment may also set a limit on the validity of charge independence.

**7263 METHOD OF DETERMINING THE SPIN AND PARITY OF A PION-HYPERON RESONANCE.** R.H.Capps.  
Phys. Rev. (USA), Vol. 122, No. 3, 929-31 (May 1, 1961).

The reaction sequence,  $M_1 + N_1 \rightarrow Y^* + M_2$ ;  $Y^* \rightarrow Y + \pi_1$ ;  $Y \rightarrow N_2 + \pi_2$  is considered, where  $M_1$  and  $M_2$  are spin-zero mesons,  $N_1$  and  $N_2$  are nucleons,  $Y$  is a  $\Lambda$  or  $\Sigma^+$  particle, and  $Y^*$  is a pion-hyperon resonance of spin  $\frac{1}{2}$  or  $\frac{3}{2}$ . The general form of the angular distribution of the particles  $\pi_1$  and  $N_2$  is written down under the assumption that final state interactions between the meson  $M_2$  and the  $Y^*$  decay particles may be neglected. If any polarization of the hyperon  $Y$  exists, the spin and parity of the resonance  $Y^*$  may be determined from this angular distribution. The structure of the spin density matrix of the  $Y^*$  is discussed.

**7264 ELECTRONIC SET-UP FOR AN EXPERIMENT OF PHOTOPRODUCTION OF  $\pi^0$ -MESONS FROM PROTONS.**  
G.Cortellesa and A.Reale.  
RC Ist. Super Sanita (Italy), Vol. 23, Pt 6, 550-74 (1960). In Italian.

Description of the circuits used in an experiment on photoproduction carried out with the 1 GeV Italian electron synchrotron at Frascati. G.Martelli

**7265 A BUBBLE CHAMBER EXPERIMENT TO MEASURE THE POLARIZATION OF THE RECOIL PROTON IN THE PHOTOPRODUCTION OF  $\pi^0$  MESONS FROM HYDROGEN.**  
L.Bertanza, P.Franzini, I.Mannelli, G.V.Silvestrini and V.Z.Peterson.  
Nuovo Cimento (Italy), Vol. 19, No. 5, 953-7 (March 1, 1960).

A rapid-cycling bubble chamber was used to measure the polarization of the recoil proton from the reaction  $\gamma + p \rightarrow \pi^0 + p$ . The experimental setup and the method of analysis of the events are described. A preliminary result is given of the polarization for a mean photon energy  $k = 725$  MeV and a centre of mass angle of  $87^\circ$ .

**7266 PHENOMENOLOGICAL STUDY OF PION PHOTOPRODUCTION WITH POLARIZED PHOTONS.**  
G.T.Hoff.

Phys. Rev. (USA), Vol. 122, No. 2, 665-9 (April 15, 1961).  
Expressions for the angular distributions and polarizations of pion photoproduction with polarized photon beams are derived from a phenomenological production matrix. The experiments necessary for the complete determination of the multipole amplitudes are discussed in general, and in particular for the case in which only contributions up to p waves in the final state are important. Complete determination requires circularly polarized beams. But if only s and p waves contribute, experiments with linearly polarized beams completely determine the production matrix. The knowledge of these amplitudes would allow the determination of the unknown p-wave scattering phase shifts ( $\alpha_{11}$ ,  $\alpha_{13}$ , and  $\alpha_{31}$ ) up to energies of about 300 MeV. Invariance properties of the angular distributions and polarizations are found and tables are given.

**7267 PION PHOTOPRODUCTION AT BACKWARD ANGLES NEAR THE SECOND NUCLEON-PION RESONANCE.**  
L. Hand and C.Schaerf.  
Phys. Rev. Letters (USA), Vol. 6, No. 5, 229-31 (March 1, 1961).

An experiment is described in which the photoproduction cross-sections of  $\pi^+$  mesons from hydrogen were measured under the two conditions: (a) photon energy 500-820 MeV, laboratory angle  $180^\circ$ ; (b) photon energy 500-770 MeV, laboratory angle  $135^\circ$ . From the results the authors conclude that at  $180^\circ$  there is strong evidence for a peak at a photon energy of  $700 \pm 7$  MeV and at  $135^\circ$  a somewhat larger and broader peak of 50 MeV width, shifted upwards by 10 MeV relative to the  $180^\circ$  data. The narrowness of the peak at  $180^\circ$  gives support to the explanation that it is the effect of a single resonant state. J.H.Gunn

**7268 SEARCH FOR THE  $\omega^0$  IN PHOTOPRODUCTION.**  
K. Berkelman, G.Cortellesa and A.Reale.  
Phys. Rev. Letters (USA), Vol. 6, No. 5, 234-6 (March 1, 1961).

Using the bremsstrahlung beam of the Frascati 1 BeV electron synchrotron the authors attempted to produce the  $\omega^0$  by the reaction  $\gamma + p \rightarrow p + \omega^0$ . If the  $\omega^0$  is, in fact, a new particle or is merely a two-pion resonant state, they claim that a rapid break-up into two pions is most likely, and thus experimentally the two processes are the same. The difference between the observed counting rate and

that expected assuming no  $\omega^0$  is put forward as evidence for the existence of this particle, despite the fact that it does not show up as strongly relative to normal double-pion production in the  $\gamma + p$  process as it does in the  $p + d$  process. J.H.Gunn

**ENERGY SPECTRA OF CHARGED PIONS PRODUCED IN pd-COLLISIONS AT 660 MeV.** H.Helfer, A.S.Kuznetsov, M.G.Mescheryakov, W.Świątkowski and V.G.Vovchenko.  
Acta phys. Polon. (Poland), Vol. 19, No. 2, 227-34 (1960).

The energy spectra of charged pions produced in pd- and pp-collisions were measured using a magnetic spectrometer. The differential cross-sections for the  $p + d \rightarrow \pi^+$ ,  $p + d \rightarrow \pi^-$ , and  $p + p \rightarrow \pi^+$  processes at  $90^\circ$  in the centre-of-mass system of two colliding nucleons were found to be  $(5.0 \pm 0.6) \times 10^{-28}$ ,  $(0.57 \pm 0.08) \times 10^{-28}$  and  $(6.7 \pm 0.7) \times 10^{-28}$  cm<sup>2</sup>/sterad, respectively. The ratio of the efficiency of positive pion production on protons in deuterons and on free protons is equal to  $0.79 \pm 0.08$ .

**MULTIPLE PRODUCTION OF PIONS.** See Abstr. 7209

**7270 TOTAL CROSS SECTIONS FOR NEGATIVE PIONS ON PROTONS AT 230, 290, 370, 427, AND 460 MeV.**  
J.C.Carls, L.K.Goodwin, R.W.Kennedy, V.Perez-Mendes and W.A.Perkins, III.  
Phys. Rev. (USA), Vol. 122, No. 1, 262-4 (April 1, 1961).

The total cross-sections were measured in the same pion beams as, and at energies identical with, those of previous  $\pi-p$  differential scattering experiments (Abstr. 11213 of 1960; 2086 of 1961). Comparisons of the total and differential scattering can be made with the dispersion theory at a given energy without introducing the systematic errors that would normally enter due to uncertainties in the parameters of more than one pion beam. The measured total cross-sections are found to agree within statistics with other measured values, and with the sums of elastic, inelastic and charge-exchange cross-sections measured at the authors' laboratory. The results are:

| E(MeV)                       | 230 ± 6 | 290 ± 7 | 370 ± 9 | 427 ± 10 | 460 ± 20 |
|------------------------------|---------|---------|---------|----------|----------|
| $\sigma_{\text{total}}$ (mb) | 58 ± 9  | 33 ± 2  | 27 ± 2  | 27 ± 2   | 28 ± 2   |

**7271 STARS PRODUCED BY  $\pi^-$  CAPTURE IN A HYDROGEN BUBBLE CHAMBER CONTAINING DISSOLVED HELIUM.** M.Schiff, R.H.Hildebrand and C.Giese.  
Phys. Rev. (USA), Vol. 122, No. 1, 265-6 (April 1, 1961).

One-pronged stars produced by  $\pi^-$  capture in a hydrogen bubble chamber containing dissolved helium were investigated. The distribution of prong lengths in the interval 0.029 to 0.64 g/cm<sup>2</sup> is presented. About one-third of the prongs in this interval are found to have a unique range corresponding to tritons from the reaction  $\pi^- + \text{He}^4 \rightarrow \text{H}^3 + n$ . Some prongs lying beyond the triton peak are identified as protons from the reaction  $\pi^- + \text{He}^4 \rightarrow \text{H}^1 + \text{He}^3$ . The fraction of pions producing stars is found to be approximately equal to the helium concentration.

**7272 THE S WAVE PION-PION INTERACTION.**  
G.R.Alicock and A.N.Kamal.  
Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 278-92 (Feb., 1961).

The pion-pion interaction was studied with an explicit appeal to the standard quantum field theory. Lowest-order perturbation theory calculations indicate that the usual renormalization procedure may imply an indefinite quantization metric. An alternative procedure, using a regulator cut-off near the nucleon mass, is therefore adopted, and on this basis the following conclusions are drawn. The short range pion-pion interaction is found to be highly repulsive in states of isobaric spin  $I = 0$  and 2, giving a hard core scattering. The short range repulsion vanishes in the states with  $I = 1$ . The long range interaction is attractive in the even isobaric spin states but is very small. An "effective" pion-pion coupling constant is obtained in terms of  $a_0$  and  $a_2$ , the hard-core radii in states of isobaric spin  $I = 0$  and 2, and  $\mu$ , the meson rest mass:

$$\lambda_{\text{eff}} \cong \frac{16\pi}{5} a_0 \mu \cong \frac{16\pi}{2} a_2 \mu.$$

**7273 EXPERIMENTAL RESULTS ON THE  $\pi-\pi$  CROSS SECTION.**

J.A.Anderson, V.X.Bang, P.G.Burke, D.D.Carmony and N.Schmitz.  
Phys. Rev. Letters (USA), Vol. 6, No. 7, 365-7 (April 1, 1961).

1275  $\pi-\pi$  inelastic scatterings were divided into 8 energy intervals covering the range of  $\omega^2$  from 5 to 27.5  $m_\pi^2$ . The exper

mental distributions were fitted with a quadratic at the lower energies and a straight line at the higher energies to extrapolate to the single pion pole. Non-pole terms were found to make an important contribution. The resulting  $\pi-\pi$  cross-section as a function of energy is consistent with a resonance at  $\omega^2 = 22 m_\pi^2$ . A. Ashmore

#### 7274 LOW-ENERGY PION SCATTERING.

J. Hamilton and T. D. Spearman.  
Ann. Phys. (USA), Vol. 12, No. 2, 172-99 (Feb., 1961).

Partial wave dispersion relations are used to investigate low-energy s-wave pion-nucleon scattering. The various terms in the relations are examined. It is shown that the Born terms are very small, and the remaining terms are of the same order of magnitude as the observed scattering amplitudes. The evidence for a low-energy pion-pion interaction from s-wave pion-nucleon scattering is examined. A comparison of the dispersion relations, for s- and p-wave partial amplitudes, is made.

#### PION-KAON SCATTERING.

M. Gourdin, Y. Noirod and P. Salin.  
Nuovo Cimento (Italy), Vol. 18, No. 4, 651-70 (Nov. 16, 1960).

A direct  $\pi-K$  interaction has been proposed as one of the possible processes responsible for the K-meson-nucleon interactions. The interaction is examined using the simplified form of the Mandelstam representation given by Cini and Fubini. A general technique is given for calculating the different partial waves, and the contribution of a direct  $\pi-\pi$  interaction to the  $\pi-K$  scattering amplitude is calculated. Assuming the S-wave to be dominant, an expression is given for the effective range approximation and an estimate is made of the importance of possible  $\pi$  crossing corrections.

J. H. Gunn

#### 7275 $\pi-N$ FORWARD DISPERSION RELATIONS WITH ELECTROMAGNETIC CORRECTIONS. A. Minguzzi.

Nuovo Cimento (Italy), Vol. 19, No. 5, 981-6 (March 1, 1961).

Meson-nucleon dispersion relations with e.m. correction to  $e^2$  order are proved, and a conjecture about the unphysical range absorptive part is discussed, together with a comment about the Chew-Low extrapolation procedure.

#### 7276 ELASTIC SCATTERING OF NEGATIVE PIONS BY PROTONS AT 230, 290, 370, AND 427 MeV.

L. K. Goodwin, R. W. Kenney and V. Perez-Mendez.  
Phys. Rev. (USA), Vol. 122, No. 2, 655-64 (April 15, 1961).

The elastic differential cross-section for the scattering of  $\pi^-$  by hydrogen was measured at laboratory-system pion kinetic energies of 230, 290, 370, and 427 MeV. The elastically scattered pions were detected by a counter telescope which discriminated against recoil protons and inelastic pions on the basis of range. Differential cross-sections were obtained at nine angles for each energy and were fitted by a least-squares programme to a series of Legendre polynomials. At the three higher energies, D waves are required to give satisfactory fits to the data. The real parts of the forward-scattering amplitudes calculated from this experiment are in agreement with the predictions of dispersion theory. The results of this experiment, in conjunction with data from other pion-nucleon scattering experiments, support the hypothesis of charge independence at these higher energies.

#### 7278 INTERPRETATION OF ELASTIC $\pi^+ - p$ SCATTERING AT 1.1 BeV. B. J. Malenka and H. S. Valk.

Phys. Rev. (USA), Vol. 122, No. 3, 934-7 (May 1, 1961).

Using a high-energy approximation, it is shown that the  $\pi^+ - p$  elastic scattering data at 1.1 BeV can be interpreted in terms of coherent scattering produced by an absorptive Gaussian well having a root-mean-square range of the size of the proton charge radius plus a short-range interaction whose principal effect is represented phenomenologically as a contribution to the S-wave.

#### 7279 $\pi^+ - p$ ELASTIC SCATTERING AT 310 MeV: RECOIL-NUCLEON POLARIZATION.

J. H. Foote, O. Chamberlain, E. H. Rogers, H. M. Steiner, C. E. Wiegand and T. Ypsilantis.

Phys. Rev. (USA), Vol. 122, No. 3, 948-58 (May 1, 1961).

The recoil-proton polarization in  $\pi^+ - p$  elastic scattering at 310 MeV incident-pion laboratory kinetic energy was measured experimentally at four scattering angles with scintillation counters. Polarization values obtained, related r.m.s. experimental errors, and mean centre-of-mass recoil angles are:  $+0.044 \pm 0.062$  at  $14.2^\circ$ ,  $-0.164 \pm 0.057$  at  $124.5^\circ$ ,  $-0.155 \pm 0.044$  at  $133.8^\circ$ , and  $-0.162 \pm 0.037$  at  $145.2^\circ$ . The sign of the polarization is defined to be positive when a preponderance of the recoil protons had

their spin vectors pointing in the direction of  $\vec{p}_i \times \vec{p}_f$ , where this quantity is the cross product of the initial and final momentum vectors of the conjugate pions. A beam of  $1 \times 10^6$  pions per sec incident upon a  $1.0 \text{ g/cm}^2$  thick liquid-hydrogen target produced the recoil protons, which were then scattered by a carbon target at a mean energy varying with recoil angle from 113 to 141 MeV. The polarization of the recoil protons was analysed by measuring the asymmetry produced in the carbon scattering. A proton beam of known polarization was used to determine the analysing ability (measured asymmetry divided by the polarization of the incident protons) of the system at each recoil angle. Values obtained for the analysing ability range from 0.41 to 0.57.

#### 7280 $\pi^+ - p$ ELASTIC SCATTERING AT 310 MeV: PHASE-SHIFT ANALYSIS.

J. H. Foote, O. Chamberlain, E. H. Rogers and H. M. Steiner.  
Phys. Rev. (USA), Vol. 122, No. 3, 959-71 (May 1, 1961).

A comprehensive phase-shift analysis was performed. The experimental data utilized include measurements of the differential and total cross-sections and of the recoil-proton polarization. The D-wave phase shifts were found to be definitely needed in order to attain an adequate fit to the data. A general search for phase-shift solutions was carried out, using S-, P-, and D-wave phase shifts. One solution — of the Fermi type — was found that fits the data significantly better than any of the other solutions obtained. The calculated errors in the phase shifts of this set vary from  $0.4$  to  $0.6^\circ$ . Because it was felt that these errors might be deceptively restrictive, the effects of small nuclear F-wave phase shifts on the results of the analysis were investigated and were found to be large: not only are the uncertainties in the original Fermi-type solution increased, but additional sets of phase shifts arise that fit the data well. One of these new solutions is similar to the original Fermi set except that the magnitudes of the phase shifts in this new fit are in general larger than those in the initial solution, and the signs of the D-wave phase shifts are reversed. The nuclear phase shifts in the original Fermi solution and their r.m.s. errors are (when F-wave phase shifts are allowed):  $S_{3,1} = -17.2 \pm 2.6^\circ$ ,  $P_{3,1} = -2.9 \pm 4.0^\circ$ ,  $P_{3,3} = 135.0 \pm 0.6^\circ$ ,  $D_{3,3} = 3.1 \pm 2.6^\circ$ ,  $D_{3,5} = -4.9 \pm 2.1^\circ$ ,  $F_{3,7} = 0.5 \pm 0.6^\circ$ ,  $F_{3,7} = -0.6 \pm 1.4^\circ$ . Although theory appears to favour this set, further theoretical and experimental evidence is desirable. The values given here for the first five phase shifts approximate the corresponding values obtained when the F-wave phase shifts were assumed negligible. However, all except  $P_{3,3}$  fall outside the limits set by the small original errors. Inelastic scattering processes were neglected during the phase-shift analysis. Calculations indicate that, if these processes could properly be taken into account, any changes in the quoted values of the phase shifts would probably be well within the corresponding errors given. Extension of the phase-shift inquiries to include G-wave was attempted but it was observed that the available data and theory do not allow the G-wave interaction to be significantly incorporated into the analysis.

#### 7281 ABSORPTION OF $\pi^+$ MESONS WITH ENERGIES OF ABOUT 50 MeV IN CARBON NUCLEI.

J. Laberrigue-Frolow, M. P. Balandine and S. Z. Orvinovski.

J. Phys. Radium (France), Vol. 21, No. 1, 54-8 (Jan., 1960). In French.

Stars due to absorption of  $\pi^+$  mesons of energy  $50 \pm 20$  MeV in carbon nuclei were studied by means of a propane bubble chamber. The cross-section is found to be  $145 \pm 36 \text{ mb}$ . The distribution of these stars as a function of the number of prongs indicates a mean number of prongs  $2.6 \pm 0.3$ . There is a noticeable anisotropy in the angular distribution of prongs relative to the direction of the incoming  $\pi^+$ . The fundamental reason of this asymmetry is probably due to quasi-elastic scattering of the  $\pi^+$  on nucleons inside the nucleus before its absorption. The distribution of two-prong stars as a function of the angle between the two prongs is given.

#### 7282 INTERMEDIATE VECTOR BOSON AND RADIATIVE LEPTON DECAY OF THE K MESON.

A. Kanazawa, M. Sugawara and K. Tanaka.

Phys. Rev. (USA), Vol. 122, No. 1, 341-4 (April 1, 1961).

K-meson decay into electron, neutrino, and photon is analysed in the lowest-order perturbation with respect to weak and electromagnetic interactions, but without making any approximation regarding the strong interaction. The weak interaction is assumed to be transmitted by a single charged intermediate vector meson, which interacts with the weak current in the conventional way. It is pointed out that a certain angular and momentum distribution of decay particles could reveal almost unequivocally whether the inter-

mediate vector meson does exist. It is shown also that other lepton decays of the K-mesons, which includes  $\mu$ -mesons and  $\pi$ -mesons, cannot be used for the same purpose.

7283 **SPIN OF THE K'.**  
C.-H. Chan.

Phys. Rev. Letters (USA), Vol. 6, No. 7, 383-5 (April 1, 1961).

Argues that the  $K^- + p \rightarrow K'^- + p$  cross-section and the K' width together indicate unit spin for K' (the new  $K-\pi$  resonance). Also considers the role of a virtual K' in  $\pi^- + p \rightarrow \Lambda + K^0$ . Both arguments use "pole approximations".  
R.J.N. Phillips

7284 **K<sup>-</sup>-MESON SCATTERING IN NUCLEAR EMULSION.**  
R.D. Hill, J.H. Hetherington and D.G. Ravenhall.

Phys. Rev. (USA), Vol. 122, No. 1, 267-72 (April 1, 1961).

Elastic single scatterings of K<sup>-</sup>-mesons by nuclei of a dilute G5 photographic emulsion were measured for energies between 30 and 80 MeV. Accurate numerical calculations of the differential scattering cross-sections were carried out by solving a Klein-Gordon wave equation for an optical-model potential of the Woods-Saxon form. Experimental and theoretical results are in good agreement both on an absolute and on a relative-variation basis if the real part of the K<sup>-</sup>-nucleon potential is attractive. The connection with low-energy K<sup>-</sup>-nucleon scattering is discussed.

## Hyperons

7285 **THEORETICAL ASPECTS OF NONLEPTONIC HYPERON DECAYS.** A. Pais.

Phys. Rev. (USA), Vol. 122, No. 1, 317-30 (April 1, 1961).

Recent experimental results on nonleptonic hyperon decays are studied on the basis of a doublet approximation for strong and weak interactions, with the implied suggestion that this higher symmetry may be more easily discernable in such reactions in which K-particles do not occur explicitly. The doublet approximation is characterized by a doublet spin I which is equal to  $\frac{1}{2}$ , 1, 0 for baryons,  $\pi$ , K, respectively and by a K spin. It is not necessary to assume that the strong K interactions are weak compared to the strong  $\pi$  interactions. For the mentioned reactions it is necessary to assume that the strong interactions which do not conserve I play a minor role compared to those which conserve I. The following refinement of the nonleptonic  $\Delta T = \frac{1}{2}$  rule is proposed (T = isotopic spin). The weak nonleptonic interactions consist of two parts  $H^{(0)}$ ,  $H^{(1)}$  with  $\Delta I = 0, 1$ , respectively. In the doublet approximation  $H^{(0)}$  and  $H^{(1)}$  separately conserve parity in the presence of all strong  $\pi$  and K interactions.  $H^{(0)}$  and  $H^{(1)}$  together do not conserve parity, however. In addition to  $\Delta I = 1$ ,  $H^{(1)}$  should in general satisfy a further constraint, but there are classes of graphs for which  $\Delta I = 1$  is sufficient. Current  $\times$  current structures for  $H^{(0)}$  and  $H^{(1)}$  are examined. Results of an earlier paper (Abstr. 5660 of 1961) can be viewed as a special case of the  $\Delta I = 0, 1$  rule. The same is true for results obtained by Feldman, Matthews, and Salam and by Wolfenstein. The considerations of these authors can be extended to wider classes of graphs. Odd relative helicity and the relation between rates for  $\Lambda \rightarrow p + \pi^-$ ,  $\Sigma^+ \rightarrow p + \pi^0$  are consequences of the  $\Delta I = 0, 1$  rule only. So is the prediction that  $\Xi$  decay is strongly P nonconserving. The parity properties of  $H^{(0)}$ ,  $H^{(1)}$  are sufficient conditions. It is a delicate question whether they are necessary. For a subset of graphs they are not necessary, but this set seems arbitrary. If it is assumed that the parity conditions are necessary, the schizon scheme is ruled out. It is noted that the nonleptonic weak interactions may be generated by the strong interactions in terms of the following prescription.  $H^{(1)}$  is generated by assuming that the  $\pi(K)$  fields have small  $K(\pi)$  components. An  $H^{(0)}$  is generated by assuming that the doublets  $N_1(N_2)$  have small  $N_2(N_1)$  components; likewise for  $N_3$  and  $N_4$ . Further, it is observed that one can construct a non-electromagnetic  $\Delta T = \frac{3}{2}$  interaction which is small in the sense that it only contributes to  $K_{\pi\pi}^+$  to the extent that the doublet approximation is not valid.

7286 **MAGNETIC MOMENTS OF THE  $\Lambda$  AND  $\Sigma$  HYPERONS.**  
K. Tanaka.

Phys. Rev. (USA), Vol. 122, No. 2, 705-11 (April 15, 1961).

A relation among the magnetic moments of  $\Sigma^+$ ,  $\Sigma^0$ ,  $\Sigma^-$ , and  $\Lambda$  is obtained as a consequence of the proposed symmetries of strong interactions, a minimal electromagnetic coupling for the electro-magnetic interactions being assumed. The magnetic moments of the  $\Lambda$  and  $\Sigma$  hyperons are calculated with the aid of mass spectral

representations in which only the contributions of the bound states are taken into account. The present calculation of these magnetic moments are compared with various other calculations. Remarks are made on the possible experimental values.

7287  **$\Sigma^0 - \Lambda^0$  RELATIVE PARITY FROM  $\Sigma^0$  DECAY.**  
L. Michel and H. Rouhaninejad.

Phys. Rev. (USA), Vol. 122, No. 1, 242-52 (April 1, 1961).

In order to establish how  $\epsilon$ , the  $\Sigma^0 - \Lambda^0$  relative parity, can be measured from actual bubble chamber experiments featuring polarized  $\Sigma^0$  production and decay, followed by  $\Lambda^0$  decay and  $\gamma$ -pair production or Dalitz pair in the  $\Sigma^0$  decay, a correlation function is constructed depending on  $\epsilon$ , another unknown parameter to be measured in the same experiment and the energy and momenta of the different particles involved. This study is Lorentz covariant, but the link with the usual "nonrelativistic" formalism is exhibited. In an appendix it is shown that the polarization of  $\Sigma^0$  produced in  $\pi^- + p^+$  reactions is expected to be large.

## Deuterons

7288 **A SOURCE OF POLARIZED DEUTERONS AND DETERMINATION OF THE POLARIZATION BY MEANS OF THE (d, T) REACTION.**

H. Rudin, H. R. Striebel, E. Baumgartner, L. Brown and P. Huber.  
Helv. phys. Acta (Switzerland), Vol. 34, No. 1, 58-84 (1961). In German.

The design, construction and testing of a source of polarized deuterons is described. Three hyperfine components of an atomic deuterium beam are separated in a strong magnetic quadrupole field. The beam then passes into a weak homogeneous field, where the atoms are ionized by electron bombardment. The gas kinetics of the formation and the polarization of the beam are discussed together with the attendant technical problems of magnetic fields and vacuum. The atomic beam intensity is predicted from theory and compared with the measured value. The ionization of the atomic beam and the resulting deuteron polarization is described. Calculations of the spin populations of the ion beam and the resulting polarization are given. The tensor polarization of the beam was measured with the  $T(d, n)He_4$  reaction. The beam consists of  $10^{-8}$  A of deuterons characterized by  $P_{33} = -0.245$ . Experiments indicate the usefulness of the device as a source of polarized protons, if the proton content of the residual gas is reduced.

7289 **DETERMINATION OF CROSS-SECTIONS OF  $D + D = p + T + 4.03$  MeV AT ENERGIES BELOW 15 keV.**  
D. Magnac-Valette, E. Lacombe, R. Bilwes and P. Cüer.

J. Phys. Radium (France), Vol. 21, No. 2, 125-6 (Feb., 1960). In French.

A thick target containing absorbed deuterium was used.

7290 **PROTON SPECTRA FROM  $D(n, p)2n$  REACTION AT 14/4 MeV.**

K. Ilakovac, L. G. Kuo, M. Petravić, I. Šlaus and P. Tomaš.  
Phys. Rev. Letters (USA), Vol. 6, No. 7, 356-8 (April 1, 1961).

The proton spectra were measured using an (E - dE/dx) counter telescope. The spectrum obtained at 4° is very similar to that obtained for the neutron spectrum in the reaction  $D(p, n)2p$  at a similar energy, although the peak at maximum proton energy is narrower and more pronounced.  
C. J. Bae

## Tritons

7291 **ANGULAR YIELD OF NEUTRONS FROM THE  $T(d, n)He^4$  REACTION FOR 6 TO 11.5 MeV DEUTERONS.**  
M. D. Goldberg and J. M. Le Blanc.

Phys. Rev. (USA), Vol. 122, No. 1, 164-8 (April 1, 1961).

The angular yield of monoenergetic neutrons from the  $T(d, n)He^4$  reaction was measured with 6.2, 7.9, 9.1, 10.2, and 11.4 MeV deuterons. The neutrons were detected with a proton recoil telescope which provided discrimination against neutrons from the  $T(d, np)T$  breakup reaction. The yield curves are all peaked forward, with a second maximum at about 65° which becomes more pronounced with increasing energy, and a back-angle rise. A quasi-absolute determination of the 0° cross-section for this reaction is described. The measured yield curves are compared with those for the companion  $He^3(d, p)He^4$  reaction and a strong similarity in shape and magnitude is noted. A simple stripping model is inadequate to describe these data. A distorted-wave calculation is required.

# COSMIC RAYS

(Nuclear reactions due to cosmic rays are included under Nuclear Reactions)

7292 ELECTROMECHANICAL METHODS OF RECORDING THE RESULTS OF EXPERIMENTS ON COSMIC RAYS AND THEIR EVALUATION BY ELECTRONIC COMPUTER. I.D.Rathgeber, C.S.Wallace and M.M.Winn. Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 1976 of 1960) p. 251-4. In French.  
The equipment consists of a number of Geiger counters, amplifiers and capacitor memories, with a Wilkinson digital convertor and a multichannel register. The convertor comes into operation just before the time of recording, which is initiated by a clock. The clock also provides a test pulse which allows all pulses from the Geiger counters to trigger a thyatron. W.G.Stripp

7293 SOME ASPECTS OF THE THEORY OF COSMIC RAY ORIGIN. V.L.Ginzburg. Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. III, p. 196-204.  
The following points are discussed with reference to the theory of cosmic ray origin: (1) The mean gas concentration in the Galaxy (including the halo). This is associated with the cosmic rays produced at the early stages of the Galaxy's evolution. (2) The mechanism and the role of cosmic ray escape from the galactic halo into intergalactic space. (3) The nature of cosmic ray movement in the galactic spiral, in connection with the problem of cosmic ray isotropy and chemical composition. (4) The origin of the cosmic ray electron component in the halo. (5) The role of different cosmic ray sources. C.F.Barnaby

7294 ELECTRONS IN THE PRIMARY COSMIC RADIATION. P.Meyer and R.Vogt. Phys. Rev. Letters (USA), Vol. 6, No. 4, 193-6 (Feb. 15, 1961).  
The flux of minimum ionizing particles with ranges less than  $120 \text{ g cm}^{-2}$  Pb, was measured at atmospheric depths of 3-5 to  $100 \text{ g cm}^{-2}$ . It is shown that the major part of this flux at the top of the atmosphere cannot be due to protons, mesons or secondary electrons, and must be due to electrons in the primary radiation. The flux of vertically incident electrons ( $\text{cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}$ ) is calculated to lie between the following limits:  $25 < E < 100 \text{ MeV}$ :  $28 - 31 \times 10^{-3}$ ;  $100 < E < 1300 \text{ MeV}$ :  $3.5 - 11 \times 10^{-3}$ ;  $1300 \text{ MeV} < E$ :  $0 - 8 \times 10^{-3}$ . J.L.Redding

7295 IONIZING RADIATION DETECTED BY PIONEER II. A.Rosen, P.J.Coleman, Jr and C.P.Sonett. Planet Space Sci. (GB), Vol. 1, No. 4, 343-6 (Sept., 1959).  
The total ionizing component of cosmic radiation was measured up to an altitude of 1550 km. An upper bound to the ratio of average-to-minimum specific ionization was determined by comparing the ionization with the count-rate observations from the Explorer IV satellite. This result implied that protons are the predominant species which gave rise to the observed ionization.

7296 OBSERVATION OF HIGH-ENERGY JET SHOWERS AND HIGH ENERGY  $\gamma$ -RAYS BY MEANS OF LARGE EMULSION CHAMBERS. Y.Fujimoto, S.Hasegawa, M.Kazuno, J.Nishimura, K.Niu and N.Ogita. Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. I, p. 41-55.

Because the main interest of cosmic-ray work is going towards the very high energy region the development of very large emulsion detectors is of increasing importance. Two types of such detectors are described, one designed to observe high energy jets and associated air shower cores and the other designed to observe high energy electrons and photons in air shower cores. The results obtained by exposing detectors of these types at an altitude of 2740 m from September 1958 to February 1958 at Mount Norikura, Japan, are described in detail. A method of reducing the scanning time of the large area is discussed. The integral spectrum of the electronic component is analysed at length. C.F.Barnaby

7297 COSMIC-RAY AIR SHOWERS AT SEA LEVEL. G.W.Clark, J.Earl, W.L.Kraushaar, J.Linsley, J.B.Rossi, F.Scherb and D.W.Scott. Phys. Rev. (USA), Vol. 122, No. 2, 637-54 (April 15, 1961).  
An investigation at sea level of cosmic-ray showers with sizes

from  $5 \times 10^5$  to over  $10^9$  particles is described. The core locations, arrival directions, and particle density distributions of several thousand showers whose cores landed within an area of  $10^5 \text{ m}^2$  were determined by the techniques of fast-timing and density sampling. The most important results are as follows: (1) the existence of primary particles with energies greater than  $10^{18} \text{ eV}$  is established by the observation of one shower with more than  $10^9$  particles; (2) the function

$$f(r) = 0.45(N/R_0^2)r^{-0.7}(1+r)^{-3.2},$$

where  $r = R/R_0$  and  $R_0 = 79 \text{ m}$ , describes the lateral distribution of particles at distances in the range  $50 \text{ m} < R < 400 \text{ m}$  and for showers with sizes in the range  $5 \times 10^5 < N < 10^8$ ; (3) at distances greater than  $50 \text{ m}$  from the core the density fluctuations in individual showers have a Poisson distribution; (4) the size and zenith angle distribution can be represented by the formula

$$s(N, x) = s_0(10^6/N)^{\Gamma+1} \exp[-(x - x_0)/\Lambda],$$

where  $x = x_0 \sec \theta$ ,  $x_0 = 1040 \text{ g cm}^{-2}$ ,  $s_0 = (6.6 \pm 1.0) \times 10^{-8} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sterad}^{-1}$ ,  $\Gamma = 1.9 \pm 0.1$ ,  $\Lambda = (113 \pm 9) \text{ g cm}^{-2}$ ,  $x_0 < x < 1.3x_0$ , and  $7 \times 10^5 < N < 7 \times 10^8$ ; (5) no evidence is found of anisotropy in the arrival directions or of a break in the energy spectrum of the primaries up to the largest energies observed; (6) assuming a specific model for shower development and taking into account fluctuations in the depth of the first interaction, the integral energy spectrum of the primaries is  $J(E) = J_0(10^{15}/E)^{\gamma}$ , where  $J_0 = (8.1 \pm 3.1) \times 10^{-11} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sterad}^{-1}$ ,  $\gamma = 2.17 \pm 0.1$ , and  $3 \times 10^{15} \text{ eV} < E < 10^{18} \text{ eV}$ .

THE CORRELATION OF SOLAR RADIO BURSTS WITH MAGNETIC ACTIVITY AND COSMIC RAYS. See Abstr. 6730

THE RELATION BETWEEN SOLAR COSMIC-RAY INCREASES AND CERTAIN RADIOFREQUENCY BURSTS. See Abstr. 6735

SOLAR RADIO BURSTS AND COSMIC RAYS. See Abstr. 6743

7298 BALLOON OBSERVATIONS OF SOLAR COSMIC RAYS ON MARCH 26, 1958. I. P.S.Freier, E.P.Ney and J.R.Winckler. Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. IV, p. 90-4.

The sequence of the solar and terrestrial events which occurred in late March, 1958, the climax of which was the observation of low energy cosmic rays arriving at the earth, is described. These events were probably initiated by a solar flare of importance three plus and of 248 minutes duration. The flare produced a type IV radio noise storm on the sun with radio emission at all frequencies observed from below 169 Mc/s. A pronounced decrease in sea level neutrons at Deep River, Canada, amounted to 9.8%. Data were obtained relating to the energy and composition of cosmic ray particles at high altitude during this period near Minneapolis (geomagnetic latitude  $55^\circ$ ). Significant features observed were the presence of particles below the normal cut-off rigidities appropriate to the latitude of Minneapolis and the delayed arrival of cosmic rays relative to the flare. C.F.Barnaby

7299 BALLOON OBSERVATIONS OF SOLAR COSMIC RAYS ON MARCH 26, 1958. II. P.S.Freier, E.P.Ney and J.R.Winckler. Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. IV, p. 88-9.

From the emulsion measurements reported in Pt I (see preceding abstract) the differential energy spectrum of protons and alpha-particles over a limited energy-range was determined. The results obtained are given and the observation of an increase in the flux of protons and low-energy alpha-particles during the period of the experiment is discussed. C.F.Barnaby

7300 THE SUDDEN INCREASE IN THE PHOTON COMPONENT OF COSMIC RADIATION ON MAY 4, 1960. S.Standil, R.P.Bukata and F.K.Chin. Canad. J. Phys., Vol. 39, No. 1, 229-30 (Jan., 1961).

The increase during the solar flare, at  $49.9^\circ \text{ N}$   $97.2^\circ \text{ W}$  and altitude 236 m, of the mu-meson component is given as 10-15%, and of the photon component as 50-60% (energy greater than 35 MeV) and 10-15% (energy between 12 and 35 MeV). The increase occurred at  $10.45 \pm 15 \text{ min}$ . See also Abstr. 20286 of 1960.

J.L.Redding

**7301 27 DAY VARIATIONS IN THE INTENSITY OF THE  $\mu$ -MESON COMPONENT OF COSMIC RAYS MEASURED WITH NARROW ANGLED COUNTER TELESCOPES.**

L.Mitrani, B.Betev, Sh.Kavilakov and D.Apostolov.  
C.R. Acad. Bulg. Sci., Vol. 13, No. 5, 519-22 (Sept.-Oct., 1960).

Two counter telescopes, with 10 cm Pb absorber, at zenith angles  $30^\circ$  north and south, were used to measure the  $\mu$ -meson flux from August 1, 1957 to December 31, 1958. After correcting for changes in barometric pressure and the height of the  $\mu$ -meson generating layer, the intensity was found to exhibit a 27 day period with amplitude 1% of the mean intensity. The north and south pointing telescopes gave the same results showing that the origin of the variations should be sought in general magnetic disturbances rather than in corpuscular streams from the sun. J.L.Redding

**7302 COSMIC RAY INTENSITY DECREASES DURING THE MAGNETIC STORM OF FEBRUARY 11th, 1958.**

S.Kavilakov, L.Mitrani and B.Betev.

C.R. Acad. Bulg. Sci., Vol. 13, No. 6, 653-5 (Nov.-Dec., 1960).

Measurements of the  $\mu$ -meson component of cosmic rays are reported; these were made by two narrow-angled counter telescopes orientated in a North-South direction at a zenith angle of  $30^\circ$  during a period around February 11, 1958. The readings, corrected for meteorological effects, show correlation with the K-index and would agree with the general intensity decrease due to the magnetic storm on February 11, 1958. E.W.Kellermann

**7303 SIDEREAL ANISOTROPY OF HIGH ENERGY COSMIC RAYS.** I.Escobar V., N.Nerurkar and R.Weil.

Planet. Space Sci. (GB), Vol. 1, No. 3, 155-60 (Aug., 1959).

An experiment detecting extensive air showers responding to primary energies greater than  $10^{14}$  eV is being conducted at Chacaltaya, Bolivia (elevation 5220 m; geographic latitude  $16^\circ$ S) with counter trays separated at least by 20 m. There is evidence of a sidereal anisotropy of about 1.6% with the time of maximum at 1400 L.S.T. The barometric coefficient is discussed in connection with the absorption curve for extensive showers.

**7304 SIDEREAL ANISOTROPY OF HIGH ENERGY COSMIC RAYS.** II. I.Escobar V., N.Nerurkar and R.Weil.

Planet. Space Sci. (USA), Vol. 2, No. 2-3, 187-92 (April, 1960).

A report is made of the results obtained from a second period of operation of an extensive shower monitor located at Chacaltaya, Bolivia. The results are consistent with those obtained during the first period of operation, namely, a variation of 1% at 19.0 local Sidereal Time for the high energy showers, and no variation for the lower energy showers recorded. It is shown that the pressure correction applied does not affect these results.

**7305 SIDEREAL ANISOTROPY IN COSMIC RAYS OF HIGH ENERGY.** I.Escobar V., N.Nerurkar and R.Weil.

Rev. Mexicana Fis., Vol. 8, No. 2, 87-100 (1959). In Spanish.

An experiment designed to study extensive air showers of cosmic rays corresponding to primary energies of the order of  $10^{14}$  to  $10^{15}$  eV was carried out at Chacaltaya (5220 m above sea level, geographical latitude  $16^\circ$ S), with coincidences between batteries of counters at 20 m separation. There was evidence of a sidereal anisotropy of the order of 1.6% with the maximum approximately at 14.00 hrs local sidereal time. The barometric coefficient in relation to the absorption curve for these showers is discussed. I.J.R.Aitchison

**7306 DAILY VARIATIONS IN THE INTENSITY OF COSMIC RAYS MEASURED BY DIRECTIONAL TELESCOPES AT CHACALTAYA.** I.Escobar V., C.Urfa and R.Weil.

Rev. Mexicana Fis., Vol. 8, No. 2, 101-15 (1959). In Spanish.

An experiment using two twin telescopes, without absorber and directed at  $45^\circ$  East and West was carried out at Chacaltaya. From the study of the data over a period of 5 months it is concluded that the principal factor in the observed variation is due to fluctuations in pressure. Making the barometric correction and eliminating the meteorological factors by taking the difference of the East and West telescopes gives the result that there is a daily variation in the primary radiation of  $\sim 3\%$  with a maximum at 12.00 hrs and a minimum at 20 hrs. The data appear to indicate that the primary particles of low energy which cause the radiation recorded in the West telescope are scattered by extraterrestrial magnetic fields. I.J.R.Aitchison

**NUCLEAR INTERACTIONS OF PROTONS, NEUTRONS, AND SHOWER PARTICLES OF VERY HIGH ENERGY IN NUCLEAR EMULSION.** See Abstr. 7238

**ON THE INITIAL STAGE OF CHARGED-PARTICLE ACCELERATION.** L.I.Dorman.

Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960) Vol. III, p. 239-44.

In this the following problems are discussed: (1) The injection energy in a solar flare in the case of charged-particle acceleration by the Fermi statistical mechanism; (2) The fraction of accelerated particles and the necessity of preliminary acceleration by the first order Fermi mechanism; (3) Acceleration of particles of the medium between approaching magnetic clouds; (4) Maximum energy of accelerated particles. C.F.Barna

**THE USE OF THE NEON FLASH TUBE AS A DETECTOR OF IONIZING PARTICLES.** See Abstr. 7163

**NUCLEUS**

**TWO-NUCLEON INTERACTION FROM DOUBLET SPLITTINGS.** F.C.Barker.

Phys. Rev. (USA), Vol. 122, No. 2, 572-7 (April 15, 1961).

The splitting of closely spaced doublet levels, of spin  $J + \frac{1}{2}$  and  $J - \frac{1}{2}$ , is investigated in cases which can be approximated by a core of spin J and an s nucleon. Allowance is made for the Thomas shifts of the levels. Using j-j coupling wave-functions, the exchange parameters and strength of the effective interaction between nucleons in the nucleus are determined by a least-squares fit to the doublet splittings and give some improvement over results obtained with previously accepted parameters. It is suggested that measurements of the sign of some doublet splittings would clarify the interaction further.

**WAVE EQUATIONS INVARIANT UNDER DISCONTINUOUS GROUPS AND THE PROBLEM OF NUCLEAR FORCES.** See Abstr. 7219

**AN ALPHA-PARTICLE MODEL FOR SOME LIGHT NUCLEI.** P.D.Kunz.

Ann. Phys. (USA), Vol. 11, No. 3, 275-305 (Nov., 1960).

The alpha-particle model is generalized to include the effects of rotational-particle coupling which mixes bands and a procedure to take into account the effect of the exclusion principle between the nucleons in the alpha particles and those outside the alpha particles. The latter nucleons are taken to interact with the alpha particles by a potential which is derived from scattering data. In the case of  $\text{Be}^9$  it was found possible to describe most of the levels below 11 MeV as belonging to either a band which has an angular momentum projection  $\frac{3}{2}$  on the alpha-alpha axis or a band that has a projection of  $\frac{1}{2}$ -. The model predicts the presence of lying positive parity levels as found experimentally. The ground-state magnetic dipole and electric quadrupole moments and the cross sections for inelastic scattering are calculated and compared with experiment. Furthermore, the model is applied to  $\text{Be}^{10}$  and the (p,  $\gamma$ ) angular correlation is computed for the reaction  $\text{Be}^9(d,p)\text{Be}^{10*}(\gamma)\text{Be}^{10}$ .

**PAIRING FORCES AND NUCLEAR COLLECTIVE MOTION.** A.K.Kerman.

Ann. Phys. (USA), Vol. 12, No. 2, 300-29 (Feb., 1961).

The influence of pairing forces on the collective vibrations of nuclei is studied using a perturbation expansion. The result is found to agree with that given by Belyaev using the superconductivity approximation except that here the number of particles is conserved. A general discussion is given of the collective quadrupole energy surface. In particular the anharmonic terms in the expansion about zero deformation and the general character of the stability of axisymmetric deformed systems are discussed.

**THE THREE-NUCLEON CLUSTER TERM ENERGY IN NUCLEAR MATTER.** H.S.Köhler.

Ann. Phys. (USA), Vol. 12, No. 3, 444-51 (March, 1961).

The three-nucleon cluster correction to the energy per nucleon is calculated for nucleon-nucleon interaction of the Serber type with hard core. An approximation due to Moszkowski and Scott was applied for solving the scattering of two nucleons in nuclear matter. It was found that although the hard core has high Fourier components the increase of the cluster correction due to this reason is largely suppressed by the exchange operator. A correction of  $-0.10$  MeV/nucleon was obtained, thus supporting the validity of the Brueckner theory.

**7312 CLUSTER NATURE OF  $\text{Li}^7$  AND  $\text{Be}^7$ .** T.A. Tombrello and G.C. Phillips. *Phys. Rev. (USA)*, Vol. 122, No. 1, 224-8 (April 1, 1961).  
Measurements of the capture  $\gamma$ -radiation processes, mass  $+\alpha \rightarrow \text{mass } 7 + \gamma$  and nucleon  $+\text{Li}^6 \rightarrow \text{mass } 7 + \gamma$ , give information about the cluster structure of the mirror nuclei  $\text{Li}^7$  and  $\text{Be}^7$ . The cluster model predicts that the ground state and low excited states of these nuclei should have large reduced widths  $\theta_{3+4}^2$  for the configuration (mass 3  $+\alpha$  particle) and small reduced widths  $\theta_{1+2}^2$  for the configuration (nucleon  $+\text{Li}^6$ ). Scattering experiments provide accurate initial, capturing, wave-functions, and an assumption of the cluster nature of the final, bound, states allows the electromagnetic capture cross-sections to be calculated and compared to experiment. The reduced widths deduced show that  $\theta_{3+4}^2$  is large,  $\theta_{1+2}^2$  is small, and that the ground states and first excited states of  $\text{Li}^7$  and  $\text{Be}^7$  are primarily of the two-body cluster form (mass  $+\alpha$  particle).

**7313 THE EFFECT OF PAIR CORRELATION ON THE MOMENT OF INERTIA AND THE COLLECTIVE GYROMAGNETIC RATIO OF DEFORMED NUCLEI.** S.G. Nilsson and O. Prior. *K. Danske Vidensk. Selsk. math.-fis. Medd. (Denmark)*, Vol. 32, No. 16, 61 pp. (1961).  
The moment of inertia and the collective gyromagnetic ratio of even-even nuclei are calculated on the basis of wave-functions that take a pairing interaction into account through the quasiparticle formalism. The results obtained theoretically are found to be in reasonable agreement with experiments. The strength of the characteristic pair-correlation matrix element to be employed is estimated on the basis of data on odd-even mass differences. The dependence of the calculational results on the central-field parameters, as for example the eccentricity and the single-particle energy scale, is discussed. Other possible effects with particular relevance to the odd-even mass difference and the experimentally occurring energy gap are also surveyed.

**7314 NUCLEAR SPIN OF  $\text{Ho}^{166}$ .** W.J. Childs and L.S. Goodman. *Phys. Rev. (USA)*, Vol. 122, No. 2, 591-4 (April 15, 1961).  
The hyperfine structure of  $\text{Ho}^{166}$  was examined by means of the atomic-beam magnetic-resonance technique. The atomic ground state appears to be  $^4\text{I}_{15/2}$ , and  $g_J$  has the measured value  $1.19509 \pm 0.00007$ , in close agreement with the Russell-Saunders value of 1. Only one resonance is observed, and its transition frequency for  $15 \leq H \leq 150$  G is proportional to the magnetic field strength to within experimental error. The simplest interpretation is that the nuclear spin is  $I = 0$ . It is shown that if  $I = 1$ , the magnetic hyperfine interaction constant must be less than 5 kc/s.

**7315 NUCLEAR SPIN AND MAGNETIC MOMENT OF  $2.6 \text{ hr Mn}^{56}$ .** W.J. Childs, L.S. Goodman and L.J. Kieffer. *Phys. Rev. (USA)*, Vol. 122, No. 3, 891-6 (May 1, 1961).  
The atomic-beam magnetic-resonance technique was used to examine the hyperfine structure of  $2.6 \text{ hr Mn}^{56}$ . The results obtained are  $I = 3$ ,  $|a| = 56.3924 \pm 0.0023$  Mc/s,  $|b| \leq 0.050$  Mc/s,  $g_J = 2.0012 \pm 0.0001$ , and  $\mu_I = +3.2402 \pm 0.0002$  n.m. The value given for the nuclear magnetic dipole moment is deduced from the Fermi-Segrè relation and is therefore subject to correction for a possible hyperfine anomaly.

**ON THE CONTRIBUTION OF THE FERMI CONTACT TERM TO THE MAGNETIC FIELD AT THE NUCLEUS.** See Abstr. 6269

**7316 SELF-CONSISTENT FIELD THEORY OF NUCLEAR SHAPES.** M. Baranger. *Phys. Rev. (USA)*, Vol. 122, No. 3, 992-6 (May 1, 1961).  
The Hartree-Fock equations are generalized to include pairing effects on the same footing with field-producing effects. In addition to the Hartree potential, there enters a pairing potential. When applied to a spherically symmetric shell-model Hamiltonian, these equations may possess deformed solutions. Application is made to pairing plus quadrupole forces, with results identical to those of Belyaev (Abstr. 4961 of 1959) and Kisslinger and Sorensen (Abstr. 17458 of 1960). The spherical shape becomes unstable when some collective vibration of the spherical nucleus reaches zero frequency.

**ELLIPSOIDAL CHARGE DISTRIBUTION OF A DEFORMED NUCLEUS.** See Abstr. 6761

**NUCLEAR RESONANCE FLUORESCENCE FROM THE 279 keV LEVEL OF  $\text{Ti}^{48}$  WITH AN ULTRACENTRIFUGE.** See Abstr. 7357

## Energy Levels

**7317 SHELL STRUCTURE EFFECT OF THE LEVEL SPACING IN HIGHLY EXCITED NUCLEI.** N. Hayano. *Bull. Kyushu Inst. Technol. Math. Nat. Sci. (Japan)*, No. 6, Pt 1, 17-28 (March, 1960).

The effect of shell structure and the dependence of angular momentum on the level spacing of a highly excited nucleus have been studied by the statistical method. The Fermi-level of a nucleus is considered as corresponding to a group of subshell levels in order to take the shell effect into account in the statistical method of counting. It is assumed that the shell pairing energy and the average potential are responsible for the remaining interactions between nucleons. The influence of degeneracy in the Fermi-level are discussed in some detail in correlation with the broken pairs of nucleons. As a test of this approach the level spacings around  $N = 82$  nuclei were calculated and convincing results obtained.

**7318 ON THE FIRST EXCITED STATES OF SPHERICAL EVEN-EVEN NUCLEI.** R. Arvieu and M. Vénérini. *C.R. Acad. Sci. (France)*, Vol. 252, No. 5, 670-2 (Jan. 30, 1961). In French.

The energies of excited states of nuclei can be calculated by methods analogous to those used in the theory of superconductivity. A form of the Hamiltonian is used which allows simple expressions to be obtained for the energies. D.J. Thouless

**7319 THE DIFFERENCE BETWEEN THE NEUTRON SEPARATION ENERGIES FOR EVEN-ODD AND EVEN-EVEN NUCLEI.** C. Ythier and R. Van Lieshout. *C.R. Acad. Sci. (France)*, Vol. 252, No. 9, 1308-10 (Feb. 27, 1961). In French.

The difference in neutron separation energies  $S_n(Z, N) - S_n(Z, N-1)$  is evaluated empirically as a function of  $N$ . The form of this function is interpreted by nuclear deformation, the completion of closed neutron shells, and the energies of the first excited states in even-even nuclei. A.M. Green

**7320 SPIN-ORBIT SPLITTING IN NUCLEI DUE TO TENSOR INTERACTION.** P. Goldhammer. *Phys. Rev. (USA)*, Vol. 122, No. 1, 207-11 (April 1, 1961).

The effect of the tensor force in nuclei with closed shells plus one nucleon is investigated using second-order perturbation theory. It is found that one can explicitly exhibit the spin-orbit splitting due to the tensor force using some simple identities. The spin-orbit splitting in  $\text{He}^8$  is computed, and found to be 3.4 MeV compared with an experimental value of 2.6 MeV.

**7321 NOTE ON COLLECTIVE EXCITATION OF ODD NUCLEI OF SUPPOSED "SPHERICAL" CORE.** O. Bergman. *Ark. Fys. (Sweden)*, Vol. 18, Paper 26, 379-84 (1960).

Aiming at a better understanding of some special excited states in the platinum isotopes, a search has been carried out for levels of possible collective character in odd nuclei. Some evidence has been found for this type of excitation in a few odd neutron nuclei.

**TRANSIENT EXCITATION OF NUCLEI IN FERROMAGNETIC METALS.** See Abstr. 6421

**7322 ENERGY LEVELS OF  $\text{B}^{10}$ : EVIDENCE FROM THE  $\text{B}^{10}$   $\gamma$ -RAY SPECTRUM.** R.B. Galloway and R.M. Sillitto. *Proc. Roy. Soc. Edinburgh A (GB)*, Vol. 65, Pt 3, 247-62 (1961).

A study of the  $\gamma$ -rays produced during the bombardment of a thick  $\text{Be}^9$  target by 600 keV deuterons was made to investigate the possible existence of a level at 2.86 MeV in  $\text{B}^{10}$ , about which contradictory reports have appeared. A spectrum of the  $\gamma$ -rays in coincidence with the 0.72 MeV  $\text{B}^{10}$   $\gamma$ -ray was obtained, and is interpreted as providing evidence for a level in  $\text{B}^{10}$  at 2.86 MeV. The relative intensities of the  $\gamma$ -rays in an ungated spectrum, and in spectra gated by the 0.72 and 1.02 MeV  $\text{B}^{10}$   $\gamma$ -rays, were found, and a decay scheme consistent with the observations is deduced. The relative intensities of the transitions in this decay scheme are consistent with the intensities of the neutron groups in a spectrum of the neutrons from this reaction. A spin value of 2 or 3 is suggested for the 2.86 MeV level.

**7323 GAMMA-RAY DE-EXCITATION OF THE LOW LEVELS OF  $\text{F}^{18}$ .** J.A. Kuehner, E. Almqvist and D.A. Bromley. *Phys. Rev. (USA)*, Vol. 122, No. 3, 908-19 (May 1, 1961).

The reaction  $\text{O}^{16}(\text{He}^3, p)\text{F}^{18}$  was employed to study the de-excitation gamma-ray branching of levels in  $\text{F}^{18}$  up to about 3 MeV

using  $\gamma\gamma$  coincidence techniques. These measurements were shown to be in reasonable agreement with tentative level identifications, 0 MeV ( $1^+$ ), 0.94 MeV ( $3^+$ ), 1.04 MeV ( $0^+$ ,  $T = 1$ ), 1.12 MeV ( $5^+$ ), 1.70 MeV ( $1^+$ ), 2.10 MeV ( $2^+$ ), 2.53 MeV ( $3^+$ ), and 3.06 or 3.13 MeV unresolved ( $2^+$ ,  $T = 1$ ), based on the intermediate-coupling shell-model predictions of Elliott and Flowers (Abstr. 5585 of 1955) and of Redlich (Abstr. 4262 of 1958). An additional level at 1.08 MeV, which may arise from core excitation, is shown likely to have spin zero. It is suggested that the predicted energies need to be reduced by a factor of 0.6 and that the  $T = 1$  levels require shifting with respect to the  $T = 0$  levels to bring them into agreement with experiment. It has not been found possible to obtain an adequate fit to the  $F^{18}$  level spectrum presented in terms of a rotational collective model. The data may, however, be qualitatively in accord with an  $\alpha - N^{14}$  cluster model interpretation. An example of the isotopic spin selection rule inhibiting  $\Delta T = 0$  M1 transitions in self-conjugate nuclei has been found.

#### 7324 EXCITED STATES IN $N^{14}$ FROM THE ELASTIC SCATTERING OF PROTONS BY $C^{13}$

E. Kashy, R.R. Perry, R.L. Steele and J.R. Risser.

Phys. Rev. (USA), Vol. 122, No. 3, 884-90 (May 1, 1961).

Excited states in  $N^{14}$  were observed by measuring the differential elastic scattering cross-section of  $C^{13}(p,p)C^{13}$  for proton energies of 2.743, 2.87, 3.105, 3.20, 3.78, 3.980, 4.04, and 4.14 MeV, corresponding to excited states in  $N^{14}$  at 10.092, 10.21, 10.428, 10.52, 11.05, 11.240, 11.30 and 11.39 MeV, respectively. Single-level dispersion theory analysis indicates assignments  $J^\pi = 1^+(2^+, 1^-, 2^+, 1^-, 1^+, 3^-, 2^-, 1^+)$ , respectively, for these states. Analysis of previously published  $C^{13}(p,p)C^{13}$  data at lower energies confirms the assignments  $1^-, 0^+, 0^-, 3^-,$  and  $1^+$  for the states at 8.05, 8.61, 8.75, 8.90, and 8.98 MeV. A resonance at 4.265 MeV corresponding to the known narrow state at 1.504 MeV was not found in the elastic scattering data although it was found to be strong in  $C^{13}(p,p')C^{13*}$ . (For previous work on  $N^{14*}$ , using deuterons on  $C^{12}$ , see Abstr. 7474 of 1960).

#### 7325 LEVELS IN $N^{14}$ AT 11.74 AND 11.82 MeV.

J.K. Bair.

Phys. Rev. (USA), Vol. 122, No. 3, 897-9 (May 1, 1961).

The known angular distribution of the  $C^{13}(p,p'\gamma)C^{13}$  3.68 MeV gamma rays is not sufficient to determine uniquely the spin and parity of the 11.74 MeV  $N^{14}$  level for the case of arbitrary channel-spin mixing. To resolve this ambiguity the angular distribution of the inelasticity scattered protons was measured. Of the previous possibilities,  $J^\pi = 1^+, 2^+$ , and  $3^-$ , the assignment  $1^+$  is selected. A new level is found at 11.82 MeV in  $N^{14}$  having a width of about 100 keV, and decaying through the 3.09 MeV level in  $C^{13}$ . An angular distribution of the inelasticity scattered protons from this new level shows strong interference effects.

#### 7326 STUDY OF THE 6.33 MeV LEVEL IN $N^{15}$ BY THE REACTION $N^{14}(d,p)N^{15}$

S. Gorodetzky, P. Fintz, G. Bassompierre and A. Gallmann.

C.R. Acad. Sci. (France), Vol. 252, No. 5, 713-15 (Jan. 30, 1961). In French.

The 6.33 MeV excited state in  $N^{15}$  was studied by the reaction  $N^{14}(d,p)N^{15}$ . The angular distribution of the protons to this state was measured at deuteron energies of 1.3 MeV and 4.5 MeV. The  $d-p-\gamma$  correlations in two planes were also measured at these two deuteron energies, the protons being detected at the stripping maximum. The results indicate  $3^-$  for the 6.33 MeV state in  $N^{15}$ .

L.L. Green

#### 7327 EXCITED STATES IN $P^{29}$ FROM THE SCATTERING OF PROTONS BY $Si^{28}$

T.A. Belote, E. Kashy and J.R. Risser.

Phys. Rev. (USA), Vol. 122, No. 3, 920-8 (May 1, 1961).

Excited states in  $P^{29}$  were observed by measuring the differential elastic scattering cross-section of  $Si^{28}(p,p)Si^{28}$  for proton energies from 2.0 to 5.0 MeV and the differential inelastic scattering cross-section of  $Si^{28}(p,p')Si^{28*}$  ( $Q = -1.78$  MeV) for proton energies from 3.0 to 5.2 MeV. Resonances were observed at 2.080, 2.88, 3.095, 3.334, 3.571, 3.710, 3.98, 4.235, 4.36, 4.43 and 4.884 MeV, corresponding to excited states in  $P^{29}$  at 4.732, 5.50, 5.711, 5.942, 6.171, 6.305, 6.57, 6.812, 6.93, 7.00, and 7.438 MeV, respectively. Single-level dispersion theory analysis indicates assignments  $J^\pi = \frac{1}{2}^+, \frac{1}{2}^-, \frac{3}{2}^+, \frac{3}{2}^-, \frac{5}{2}^+, \frac{5}{2}^-, \frac{7}{2}^+, \frac{7}{2}^-, \frac{9}{2}^+, \frac{9}{2}^-,$  and  $\frac{5}{2}^-$ , respectively, for these states.

#### 7328 COULOMB EXCITATION OF $Ta^{181}$ BY 5.5 AND 6.5 MeV PROTONS.

N. Martalogu, E. Ivanov and D. Ploștinaru.

Rev. de Physique (Roumania), Vol. 5, No. 2, 217-28 (1960). In French.

Coulomb excitation at high bombarding energies was investigated by using the proton beam from the I.F.A. cyclotron. The beam was focused into a 5 mm spot using two quadrupole lenses, and measured with a beam integrator. Gamma-rays were detected in a 40 mm NaI crystal on a R.C.A. 5819 photomultiplier, and the pulses analysed with a 64-channel analyser. Iron foils were used to reduce the intensity of the K X-rays from tantalum atoms. Reduced widths of the levels at 136 and 303 keV agreed with previous results. Gamma-rays were also found at 368 and 503 keV, and it is suggested that the former may be formed in the  $Ta^{181}(p,n)W^{181*}$  reaction. This suggests that 6.5 MeV is about the upper limit for the bombarding energy.

A. Ashmc

## NUCLEAR DECAY RADIOACTIVITY

#### 7329 MEASUREMENT OF TIME INTERVALS FOR TIME CORRELATED RADIOACTIVE DECAY.

H. Lindeman, E. Mornel and U. Galil.

Physica (Netherlands), Vol. 26, No. 11, 961-6 (Nov., 1960).

The distribution of time intervals between successive counts was measured for radioactive decay in the thorium series. The measurements show that the classical Marsden-Barratt law (1913) does not apply to this case of time correlated decay. They seem, however, to be in agreement with the theory of Lindeman-Rosen (1959) taking into account that the counter receives only the radiation emitted in a solid angle near to  $2\pi$ .

#### 7330 ANALYSIS OF SCINTILLATION SPECTROMETER OBSERVATIONS OF $Co^{60}$ AND $Na^{24}$ GAMMA RADIATION THROUGH CADMIUM.

K.A. Mahmoud and M.S. El-Nesr.

Radiation Research (USA), Vol. 14, No. 1, 17-22 (Jan., 1961).

The source of radiation was embedded in a block of cadmium slabs and the pulse spectrum plotted for the radiation emerging from the block after transmission through one of four cadmium thicknesses. Graphs of the ratio of scattered to unscattered energy flux were plotted against incident photon energy and agreement with theoretical calculations (for tin) was good in the high-energy range. Reasons for the discrepancies are discussed.

J.R. Mall

#### 7331 THE SHIELDING OF RECTANGULAR $\gamma$ -RAY SOURCE

D.P. Osanov and E.E. Kovalev.

Atomnaya Energiya (USSR), Vol. 6, 670 (1959). In Russian. English translation in: Reactor Science (GB), Vol. 12, No. 4, 215-17 (Aug., 1960).

The attenuation of  $\gamma$ -radiation from a finite rectangular source in the form of an infinitely thin lamina is discussed theoretically on the assumption that the active material is uniformly distributed over the source surface. The values of the  $\gamma$ -radiation dose rate, calculated from the formula obtained, are plotted in the form of nomograms as function of  $\mu d$  ( $\mu = \gamma$ -absorption coefficient,  $d =$  shield thickness), for various values of  $n$ , the ratio of source length to its breadth. The dependence of the dose rate on distance for various source geometries is also shown graphically and a correction for multiple scattering of  $\gamma$ -rays in the shield is briefly discussed.

I.C. Demetsopoul

#### 7332 DETECTION OF PLUTONIUM IN THE AIR BY THE APPLICATION OF COINCIDENCE TECHNIQUES.

A. Blanc and G. Roux.

Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 163-8. In French.

Air is pumped through a filter paper leaving deposits of radon or thorium. These emit  $\alpha$ -particles followed shortly afterwards by  $\beta$ -particles. A scintillator sensitive to  $\alpha$ -particles is mounted above the filter and one sensitive to  $\beta$ -particles below. The radon or thorium activity is determined from the pseudo-coincidences which it generates, and is subtracted from the total activity.

W.G. Strit

### 7333 THE MONITORING OF RADIOACTIVE EFFLUENTS. G.D.Smith.

Nuclear Electronics Conference, Paris, 1958, Vol. II (see Abstr. 12720 of 1960) p. 193-207.

Because of the low levels of activity permitted in river water, measurements must be made on samples in which the activity is concentrated by evaporation. When effluent is pumped out to sea the permitted activities are higher, and continuous monitoring is possible. A sampling vessel is described in which the volume is kept constant by a pump. Some ratemeter and integrator circuits are described.

W.G.Stripp

### HIGH-EFFICIENCY GEIGER MÜLLER COUNTER FOR MEASURING FLOWING RADIOACTIVE LIQUIDS. See Abstr. 7165

#### HALF-LIFE OF Cs<sup>137</sup>.

7334 H.Farrar, A.K.Dasgupta and R.H.Tomlinson.

Canad. J. Chem., Vol. 39, No. 3, 681-3 (March, 1961).

The half-life was found to be  $30.4 \pm 0.4$  years by determining the amount of Ba<sup>137</sup> produced in various times from a known number of Cs<sup>137</sup> atoms. The numbers of barium and caesium atoms were determined from isotope dilution data obtained with a mass spectrometer.

#### HALF-LIVES OF Rb<sup>84</sup>, Sr<sup>84</sup>, Y<sup>84</sup>, Rb<sup>85</sup>, Sr<sup>85</sup>, Y<sup>85</sup>.

7335 K.Fritze, T.J.Kennett and W.V.Prestwich.

Canad. J. Chem., Vol. 39, No. 3, 675-80 (March, 1961).

The existence of a new rubidium isotope, Rb<sup>84</sup>, has been established and its half-life measured. The half-life of this fission product was determined using the technique of timed precipitations. The value obtained for Rb<sup>84</sup> was  $2.9 \pm 0.3$  sec. With this same technique only an upper limit of 2.5 sec. could be assigned to Rb<sup>85</sup>. The half-lives of the strontium and yttrium daughters were also determined. The strontium isotopes were studied both by timed precipitations and direct measurements. The half-lives of Sr<sup>84</sup> and Sr<sup>85</sup> were found to be  $1.36 \pm 0.06$  min and  $0.8 \pm 0.15$  min, respectively. Direct measurements lead to half-lives of  $20.35 \pm 0.20$  min for Y<sup>84</sup> and  $10.9 \pm 0.2$  min for Y<sup>85</sup>.

#### DECAY OF A NEW ISOTOPE, S<sup>30</sup>.

7336 E.L.Robinson, J.I.Rhode and O.E.Johnson.

Phys. Rev. (USA), Vol. 122, No. 3, 879-84 (May 1, 1961).

Scintillation techniques were used to study the beta and gamma radiation from high-purity natural silicon targets after irradiation with 8 MeV Ne<sup>3</sup> ions. In addition to activities associated with well-known radionuclides, an activity with a  $1.35 \pm 0.10$  sec half-life was observed. A  $677 \pm 10$  keV gamma-ray associated with the 1.35 sec half life. Decomposition of decay curves constructed from data obtained by observing annihilation radiation revealed a component with the same half-life. Half-life measurements using positrons with energies in excess of 3.15 MeV also indicated the presence of a 1.35 sec activity. The beta spectrum in coincidence with two annihilation quanta extended to  $\sim 5.0$  MeV, a higher energy than can be accounted for by positrons from the known reaction products. The beta spectrum in coincidence with the  $677 \pm 10$  keV gamma ray had an end-point energy of  $4.30 \pm 0.15$  MeV. The assignment of the  $1.35 \pm 0.10$  sec activity to the decay of S<sup>30</sup>, produced in the reaction Si<sup>28</sup>(He<sup>3</sup>,n)S<sup>30</sup>, and the proposed decay scheme, are supported by arguments formulated from the known characteristics of reaction products, half-life studies using both beta and gamma radiation, the features of the experimental beta and gamma spectra, beta-gamma coincidence spectra, nuclear systematics, and nuclear theory. The decay of the ground state of S<sup>30</sup> takes place by at least two positron transitions:  $\beta_1$  a  $4.98 \pm 0.15$  MeV superallowed transition to the  $1+$ ,  $T = 0$  ground state of P<sup>30</sup>;  $\beta_2$ , a  $4.30 \pm 0.15$  MeV superallowed transition to the  $0+$ ,  $T = 1$ ,  $0.677 \pm 0.010$  MeV first excited state of P<sup>30</sup>. No evidence was found for  $\beta_3$ , presumably an allowed transition to the  $1+$ ,  $0.704 \pm 0.005$  MeV second excited state of P<sup>30</sup>, but an experimental upper limit of 25% is placed on its branching percentage. Branching percentages of  $(19 \pm 2)\%$ ,  $(73 \pm 7)\%$ , and  $(8 \pm 10)\%$  for  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$  were calculated using the measured S<sup>30</sup> half-life, a S<sup>30</sup>-P<sup>30</sup> mass difference of  $6.01 \pm 0.15$  MeV, assumed charge independence of nuclear forces, and the fact that log ft for  $0^+ \rightarrow 0^+$  positron transitions within  $T = 1$  charge multiplets is almost constant.

#### ON A METHOD OF RAPID SEPARATION OF THE

7337 ACTIVITY OF THE DECAY PRODUCTS OF RADON, THORIUM-B AND THE LONG-LIVED ACTIVITY OF THE ATMOSPHERIC AEROSOLS BY THE ANALYSIS OF THE GENERAL  $\alpha$  OR  $\beta$  DECAY CURVES. B.Amov and Kh.Kamborov.

B.R. Acad. Bulg. Sci., Vol. 13, No. 6, 649-52 (Nov.-Dec., 1960).

1 French.

An easy method of determining the decay constants of the  $\alpha$  and

$\beta$  decay of the radioactivity present in the atmospheric aerosols is described. The method consists in measuring the activity for a period of about 4 hours and then dividing the general decay curve in two parts, one corresponding to the decay of the products of radon and the other to the decay of ThB. The authors report that ten experimental curves were analysed using their method and the values of the decay constants for the long-lived activity as well as for the activity of ThB can be obtained with an accuracy of 10% if the statistical accuracy of the experimental measurement is within 10%. The analysis of one experimental curve is given as an illustration.

J.B.Garg

### 7338 RESIDUAL PRESENCE OF BORON, SODIUM AND POTASSIUM IN HEAVY-METAL RADIOACTIVE

$\alpha$ -RAY SOURCES. M.Ader.

J. Phys. Radium (France), Vol. 21, No. 2, 102-4 (Feb., 1960). In French.

Radioactive sources of Po, Pu, Th and Ac emit, in addition to the  $\alpha$ -rays, three groups of particles, lighter than  $\alpha$ , and which have a maximum range of about  $340 \mu$  in photographic emulsion. Former researches (Abstr. 3328, 5293 of 1958) showed that these light particles come neither from the gases of the ambient atmosphere, nor from the source holder, nor from contamination by other radioactive substances or by Al. The proton spectra obtained by action of  $\alpha$ -rays of Po on boron, sodium and potassium compounds were plotted. Comparison between these spectra and that of abnormally long-range particles emitted by the Po source removes the hypothesis of contamination of that source by boron, sodium or potassium compounds.

### 7339 SOME CONSIDERATIONS CONCERNING THE NUCLEAR MATRIX ELEMENT $\Sigma |B_{ij}|^2$ IN BETA DECAY.

D.S.Harmer and M.L.Perlman.

Phys. Rev. (USA), Vol. 122, No. 1, 218-23 (April 1, 1961).

Evidence that the nuclear matrix element  $\Sigma |B_{ij}|^2$  contributes to first-forbidden transitions may be deduced from the electron-capture-positron-emission ratios observed in these transitions and from an analysis of the energy and Z dependence of the coefficients of all the nuclear matrix elements involved. The analysis of these coefficients for the capture and for the emission processes shows that it is reasonable to expect that, except for  $\Sigma |B_{ij}|^2$ , these transitions would be characterized by essentially the same capture-positron ratios as those characteristic of allowed transitions. Consequently the deviations of the observed ratios from the allowed values would be due to contributions from  $\Sigma |B_{ij}|^2$ ; and the magnitude of the deviation, in a particular case, together with lifetime information may be used to compute values for this matrix element and for the sum of the others. Value are thus computed from available experimental data for three  $2 \rightarrow 2$  + transitions, and these are compared with values derived directly from theory of Rose and Osborne. In each case the value of  $\Sigma |B_{ij}|^2$  computed from experiment is nearly as large as the theoretical  $\Sigma |B_{ij}|^2$  value calculated for nucleon spin change two and is considerably larger than those calculated for spin change zero or one; furthermore, the "observed" value for the sum of the other matrix elements is considerably smaller than the largest single matrix element calculated for spin change zero or one. These results are consistent with the conclusion that the nuclear states involved are of such a nature that the transitions proceed unhindered only via  $\Sigma |B_{ij}|^2 \Delta j = 2$ . One arrives at the same conclusion on the basis of the shell model description of these nuclear states. For  $2 \rightarrow 0$  + transitions, which can be effected only by  $\Sigma |B_{ij}|^2$ , the "observed" and theoretical values of the matrix element are in good agreement; and it is of interest to note that both the theoretical and "observed" values of  $\Sigma |B_{ij}|^2$  in each of these  $2 \rightarrow 0$  + transitions are about the same or smaller than the values for the  $2 \rightarrow 2$  + transition in the same nucleus.

### 7340 EXACT SHAPE OF THE $\beta$ -SPECTRUM FROM Au<sup>198</sup>.

P.Depommier and M.Chabre.

C.R. Acad. Sci. (France), Vol. 252, No. 11, 1587-9 (March 13, 1961). In French.

A precise measurement of the shape of the  $\beta$ -ray spectrum from a thin source of Au<sup>198</sup> was made using a Siegbahn-Slätis type of spectrometer. The authors report that the shape factor is represented by  $S = [1 + g(W_0 - W)]^2$  with values of  $g = 0.034 \pm 0.004$  and  $W_0 = (962 \pm 1)$  keV, which do not agree with the earlier measurements. The accuracy of their results has been checked by the measurement of the  $\beta$ -ray spectrum from a Na<sup>24</sup> source.

J.B.Garg

DECAY OF Ba<sup>139</sup>.

7341 J.Jastrzębski.

J. Phys. Radium (France), Vol. 21, No. 1, 12-16 (Jan., 1960). In French.

The disintegration of Ba<sup>139</sup> was investigated by means of a magnetic  $\beta$ -spectrometer, working in  $\beta$ - $\gamma$  coincidence, a  $\gamma$ -spectrometer and a slow-fast coincidence circuit. Four  $\beta$ -ray branchings were found with following maximum energies and log ft:  $\beta_1$  (E-2 300 keV; 7.0),  $\beta_2$  (E-2 140 keV; 7.0),  $\beta_3$  (E-1 400 keV; 6.6) and  $\beta_4$  (E-900 keV;  $\sim 7$ ). The existence of two new levels of La<sup>139</sup> was verified by coincidence measurements and the analysis of  $\beta$ -spectrum. The half-life of 166 keV level has been found to be  $(1.7 \pm 0.2) 10^{-9}$  sec. A level scheme for the disintegration of Ba<sup>139</sup> is proposed.

RADIATIONS FROM Ba<sup>141</sup>.

7342 K.Nagatani.

J. Phys. Soc. Japan, Vol. 15, No. 1, 1-2 (Jan., 1960).

Beta- and gamma-rays from 18 min Ba<sup>141</sup> were investigated using scintillation spectrometers. Ba<sup>141</sup> was produced by photo-fission of natural uranium. The end-point energy of the beta-ray was found to be 2.8 MeV and gamma-rays of energies 0.125, 0.19, 0.28, 0.37, 0.46 and 0.61 MeV were observed.

NEW ISOTOPE OF CARBON: C<sup>16</sup>.

7343 S.Hinds, R.Middleton, A.E.Litherland and D.J.Pullen.

Phys. Rev. Letters (USA), Vol. 6, No. 3, 113-15 (Feb. 1, 1961).

The reaction C<sup>14</sup>(t,p)C<sup>16</sup> was observed by bombardment of targets containing 33% C<sup>14</sup> with 6 MeV tritons from a van de Graaff generator and magnetic analysis of the proton groups produced. The Q value of the reaction was found to be  $-3.014 \pm 0.016$ , giving a mass of  $16.014702 \pm 0.000017$  mass units for C<sup>16</sup> on the scale giving zero mass excess for C<sup>12</sup>.  $\beta$ -decay of C<sup>16</sup> proceeds via neutron unstable states in N<sup>16</sup>. Using a mechanically interrupted beam and a neutron detector consisting of BF<sub>3</sub> counters in a polystyrene block, together with an electronic time-analyser to observe the delayed neutrons from these states, the half-life of C<sup>16</sup> was found to be  $0.74 \pm 0.03$  sec. R.E.Meads

DECAY OF 49 MIN Cd<sup>118</sup> AND 5.1 SEC In<sup>118</sup>.

7244 C.E.Gleit and C.D.Coryell.

Phys. Rev. (USA), Vol. 122, No. 1, 229-31 (April 1, 1961).

The decay properties of 49 min Cd<sup>118</sup> and its daughter 5.1 sec In<sup>118</sup> are established. Cd<sup>118</sup> has a low  $\beta$ -decay energy and seems to be an allowed transition. In<sup>118</sup> has  $(4.2 \pm 0.4)$  MeV  $\beta$ -decay energy, with about 15% of the decays going to the 1.22 MeV excited state of Sn<sup>118</sup>, both  $\beta$ -transitions being allowed. It is proposed that a previously identified 4.5 min In species is a high-spin isomer In<sup>118m</sup> not formed in the  $\beta$ -decay of Cd<sup>118</sup> or formed directly in uranium fission.

THREE NEW ISOTOPES, Co<sup>63</sup>, Ga<sup>75</sup>, AND As<sup>81</sup>.

7345 H.Morinaga, T.Kuroyanagi, H.Mitsui and K.Shoda.

J. Phys. Soc. Japan, Vol. 15, No. 2, 213-17 (Feb., 1960).

Three previously unknown isotopes, Co<sup>63</sup>, Ga<sup>75</sup>, and As<sup>81</sup> were identified from the ( $\gamma$ , p) reactions on natural nickel, germanium, and selenium. Their radiations were investigated with the aid of scintillation spectrometers. Decay characteristics are as follows:

|                  | half-lives        | $\beta$ -decay energies | $\gamma$ -rays  |
|------------------|-------------------|-------------------------|-----------------|
| Co <sup>63</sup> | 52 $\pm$ 5 sec    | 3.6 $\pm$ 0.2 MeV       | No              |
| Ga <sup>75</sup> | 2.0 $\pm$ 0.2 min | 3.3 $\pm$ 0.2 MeV       | (0.36) 0.58 MeV |
| As <sup>81</sup> | 31 $\pm$ 2 sec    | 3.8 $\pm$ 0.2 MeV       | No              |

SMALL-ORDER SHAPE FACTORS IN In<sup>114</sup>, P<sup>32</sup> AND Y<sup>90</sup>.

7346 R.T.Nichols, R.E.McAdams and E.N.Jensen.

Phys. Rev. (USA), Vol. 122, No. 1, 172-81 (April 1, 1961).

The beta spectra of In<sup>114</sup>, P<sup>32</sup>, and Y<sup>90</sup> were studied closely in an intermediate-image beta-ray spectrometer and compared to theoretical predictions in terms of a linear shape factor of the form  $(1 + aW)$ . The values obtained for a were  $(+0.0036 \pm 0.0021)/mc^2$  for In<sup>114</sup>,  $(-0.0133 \pm 0.0011)/mc^2$  for P<sup>32</sup>, and  $(-0.0047 \pm 0.0008)/mc^2$  for Y<sup>90</sup>, all for electron kinetic energies from about 200 keV up to near the maximum beta energies. Tests were made to give indications for spectrometer fidelity. Because of the linearity of the shape-factor plots and the similarity in energy range, the comparative results from In<sup>114</sup>, P<sup>32</sup>, and Y<sup>90</sup> are taken as a definite indication that for at least two of these activities the shape factors have nonzero slopes, irrespective of questions of instrumental fidelity.

DECAY OF Na<sup>26</sup>.

7347 E.L.Robinson, B.T.Lucas and O.E.Johnson.

Phys. Rev. (USA), Vol. 122, No. 1, 202-6 (April 1, 1961).

The bombardment of high-purity natural magnesium targets with fast neutrons from the Li<sup>7</sup>(d,n)Be<sup>8</sup> reaction ( $E_n < 24$  MeV) yielded, in addition to activities associated with well-known isotopes, an activity having an experimental half-life of  $1.03 \pm 0.06$  sec. Scintillation spectrometer measurements showed a  $1.82 \pm 0.03$  MeV gamma-ray and a  $6.7 \pm 0.3$  MeV beta group decaying with the 1.03 sec half-life. The 6.7 MeV beta group was found to be in coincidence with the 1.82 MeV gamma ray. The assignment of the  $1.03 \pm 0.06$  sec half-life to Na<sup>26</sup> produced in the reaction  $Mg^{26}(n,p)Na^{26}$  and the proposed decay scheme are supported by internally consistent arguments based on the known characteristics of the reaction products and their decay modes; the half-life studied using both beta and gamma radiation; the features of experimental beta and gamma spectra; and nuclear systematics. The decay of the ground state of Na<sup>26</sup> takes place in part by a  $6.7 \pm 0.3$  MeV beta transition to the (2+) first excited state of Mg<sup>26</sup>. The intensities of the beta transitions to the (2+) second excited state and (0+) ground state are less than 0.1 of the intensity of the  $6.7 \pm 0.3$  MeV transition. The possible ground-state spin and parity assignment for Na<sup>26</sup> is either 1+, 2+, or 3+. A weak theoretical argument against spin 1 is presented. The present experimental measurements alone will not reduce the ambiguity in the spin assignment. A Na<sup>26</sup>-Mg<sup>26</sup> mass difference of  $8.5 \pm 0.3$  MeV is derived from the known level structure of Mg<sup>26</sup> and the beta transition energy measured in the present investigation.

STUDY OF THE FIRST FORBIDDEN TRANSITION

(3- $\rightarrow$ 2+) ON Eu<sup>152</sup> BY MEANS OF THE CORRELATION BETWEEN THE ELECTRON AND  $\gamma$ -RAY POLARIZATION.

J.Berthiers, R.Lombard and J.W.Sunier.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 257-9 (Jan. 9, 1961). In French.

The correlation between the electron and  $\gamma$ -ray polarization in the first forbidden  $\beta$ -transition in the decay of Eu<sup>152</sup> is used to place limits on the matrix elements for the transition. Several groups of values are possible and these are further limited by the  $\beta$ - $\gamma$  angular correlation. L.L.Gre

ELECTRON AND POSITRON HELICITY IN  $\beta$ -DECAY.

See Abstr. 7229

BETA-GAMMA DIRECTIONAL CORRELATION IN THE DECAY OF Ag<sup>111</sup>.

7349 J.H.Hamilton, B.G.Pettersson and J.M.Hollander.

Ark. Fys. (Sweden), Vol. 18, Paper 16, 273-81 (1960).

The directional correlation between the once-forbidden, non-unique 690 keV beta group and the 340 keV gamma ray in the decay of Ag<sup>111</sup> was measured as a function of beta energy from 153 to 595 keV. A magnetic lens spectrometer was used as the beta analyser. The observed correlation is nearly isotropic. The anisotropy increases in a negative direction from  $\sim 0$  at 150 keV to  $-0.023 \pm 0.005$  at 595 keV. A comparison with theory indicates the cancellation among the nuclear matrix elements governing the beta decay is required to explain the small anisotropy. The energy dependence of the correlation indicates that second order terms should be included in the theoretical analysis. This is in agreement with the non-statistical shape observed for the 690 keV beta group.

$\beta$ - $\gamma$  CIRCULAR POLARIZATION CORRELATION IN

7350 Sc<sup>46</sup> AND V<sup>48</sup>. H.Daniel and M.Kuntze.

Z. Phys. (Germany), Vol. 162, No. 2, 229-34 (1961). In German.

Measured by comparison with Co<sup>60</sup>, whose value was assumed to be  $A = -1/3$ . The values for Sc<sup>46</sup> and V<sup>48</sup> were found to be  $A = 0.10 \pm 0.02$  and  $A = 0.00 \pm 0.04$ , respectively. This excludes large Fermi-Gamow-Teller interference terms. Small interference terms are somewhat more likely than pure Gamow-Teller transitions in both cases.

GAMMA-GAMMA DIRECTIONAL CORRELATIONS

IN Cs<sup>133</sup>. A.P.Arya.

Phys. Rev. (USA), Vol. 122, No. 2, 549-55 (April 15, 1961).

Directional correlation measurements were made on the 356-82 keV, 301-82 keV, and 80-82 keV gamma-gamma cascades in Cs<sup>133</sup>, following the decay of 8-year half-life Ba<sup>133</sup>, with a coincidence scintillation spectrometer using NaI detectors. The observed correlation functions are:

$$W(\theta) = 1 + (0.042 \pm 0.005)P_2(\cos \theta) - (0.0041 \pm 0.0038)P_4(\cos \theta)$$

$$W(\theta) = 1 - (0.0257 \pm 0.011)P_2(\cos \theta) - (0.0002 \pm 0.008)P_4(\cos \theta)$$

and

$W(\theta) = 1 + (0.0487 \pm 0.017)P_2(\cos\theta) + (0.0011 \pm 0.012)P_4(\cos\theta)$ , respectively, for the three cascades. These gamma-gamma directional correlations were found to be consistent with spin assignments of  $\frac{1}{2}^+$ ,  $\frac{3}{2}^+$ ,  $\frac{3}{2}^+$ , and  $\frac{1}{2}^+$  to the levels at the ground state, 82 keV, 162 keV, 383 keV, and 438 keV in  $\text{Cs}^{133}$ . The probable assignment of the multipolarities for different gamma rays is as follows: The 356 keV gamma-ray is pure E2. The 82 keV gamma-ray is a mixture of (96.5  $\pm$  0.5)% M1 and (3.5  $\pm$  0.5)% E2 with  $\delta_{82} = -0.190 \pm 0.014$ . The 301 keV gamma-ray can have one of two possible mixtures: either  $\delta_{301} = +0.123 \pm 0.004$  with a mixture of (98.5  $\pm$  1.0)% M1 and (1.5  $\pm$  1.0)% E2, or  $\delta_{301} = -3.98 \pm 1.02$  with a mixture of (6  $\pm$  2)% M1 and (94  $\pm$  2)% E2. The value of  $\delta_{301} = -3.98 \pm 1.02$  is more probable. The 80 keV gamma-ray is also found to have two possible values of  $\delta_{80}$ : either  $\delta_{80} = +0.47 \pm 0.09$  with a mixture of (82  $\pm$  6)% M1 and (18  $\pm$  6)% E2 or  $\delta_{80} = +7.0$  with a mixture of (2.0  $\pm$  1.5)% M1 and (98.0  $\pm$  1.5)% E2.

7352 ANGULAR CORRELATION MEASUREMENTS IN THE DECAY OF  $\text{In}^{114m}$ . M.Kawamura.

J. Phys. Soc. Japan, Vol. 15, No. 1, 3-8 (Jan., 1960).

The directional correlation and the polarization-direction correlation of the 722 keV/556 keV gamma-gamma cascade in  $\text{Cd}^{114}$  were measured. It was found that the decay sequence of this cascade agrees well with the 4(E2)2(E2)0 sequence. The ratio of the rate of the positron decay to that of the cascade decay is also obtained as  $3 \times 10^{-3}$ .

7353 DETERMINATION OF THE DISINTEGRATION RATE OF NUCLIDES DECAYING BY ELECTRON CAPTURE.

J.R.S.Drouin and L.Yaffe.  
Canad. J. Chem., Vol. 39, No. 3, 717-28 (March, 1961).

In an attempt to determine disintegration rates of nuclides decaying by electron capture, various properties of a  $2\pi$  proportional counter spectrometer were studied. These included gas multiplication, energy resolution, and energy linearity. The result of varying anode size, gas pressure, and nature of the gas was also investigated. An experimentally determined average path length for characteristic X-ray energies between 4 and 24 keV was found.

7354 STUDY OF THE K AND L AUGER ELECTRONS OF  $\text{Ba}^{137}$ . P.Marguin and A.Mussa.

J. Phys. Radium (France), Vol. 21, No. 3, 149-56 (March, 1960). In French.

Using a double-focusing magnetic spectrometer with iron-free coils, the energies and relative intensities of the groups of Auger K lines resulting from the decay of  $\text{Cs}^{137}$  were determined. Auger L electrons were also studied.

7355 CONVERSION AND AUGER (K AND L) ELECTRONS IN THE DECAY  $\text{Tm}^{170} - \text{Yb}^{170}$ . P.Marguin and M.A.Moussa.

J. Phys. Radium (France), Vol. 21, No. 1, 17-23 (Jan., 1960). In French.

Spectra of internal conversion electrons and Auger K and L electrons from the decay of  $\text{Tm}^{170}$  were studied with a iron-free double-focusing spectrometer and uniform thin sources. The ratios K/L, L/M and L/I/LII/LIII were determined and also the intensity ratios of Auger electrons KLX/KLL. The method of postacceleration of electrons permitted study of Auger L electrons.

7356 DECAY OF  $\text{K}^{42}$  AND  $\text{Sc}^{44}$ .

J.D.McCullen and J.J.Kraushaar.  
Phys. Rev. (USA), Vol. 122, No. 2, 555-65 (April 15, 1961).

The low excited states of  $\text{Ca}^{42}$  and  $\text{Ca}^{44}$  were studied in the decay of  $\text{K}^{42}$  and  $\text{Sc}^{44}$ , with special emphasis on the observation of weakly populated states. In the  $\text{K}^{42}$  decay, gamma rays were seen at 0.31 MeV (1.1%), 0.49 MeV (<0.1%), 0.60 MeV (0.1%), 0.90 MeV (0.1%), 1.02 MeV (0.1%), 1.52 MeV (100%), 1.92 MeV (0.3%), and 2.42 MeV (0.2%). The coincidence sequence of the transitions was measured and a level scheme constructed. In the  $\text{Sc}^{44}$  decay, gamma rays were seen with energies and intensities of 0.68 MeV (3.2%), 1.02 MeV (3.1%), 1.12 MeV (4.7%), 1.16 MeV (100%), 1.50 MeV (1.7%), 1.72 MeV (0.8%), 2.28 MeV (0.2%), and 2.69 MeV (0.2%). Coincidence measurements were also taken for this nuclide to clarify the cascade sequences, and a level scheme was constructed. A search was made for low-energy conversion electrons ( $E < 1$  MeV) in an effort to establish the existence or nonexistence of a low-lying  $0^+$  state in  $\text{Ca}^{44}$ , whose analogue occurs as the second excited 0.84 MeV state in  $\text{Ca}^{42}$ . No such conversion electrons were seen, by either electron spectrometer studies or by electron-delayed gamma-ray coincidence measurements. An upper limit of 0.05% of the total decay of  $\text{Sc}^{44}$  was put on the population of such a state.

7357 NUCLEAR RESONANCE FLUORESCENCE FROM THE 279 keV LEVEL OF  $\text{Tl}^{203}$  WITH AN ULTRA-CENTRIFUGE. B.I.Deutch and F.R.Metzger.

Phys. Rev. (USA), Vol. 122, No. 3, 848-54 (May 1, 1961).

Resonance fluorescence from the 279 keV level of  $\text{Tl}^{203}$  was studied with the centrifuge method. Assuming a total conversion coefficient  $\alpha_T = 0.225$ , a mean life  $\tau_\gamma = (5.00 \pm 0.24) \times 10^{-10}$  sec for gamma-ray emission was calculated from the resonance scattering measured at different source velocities. Combining this lifetime with the B(E2) from Coulomb excitation, the absolute value of the mixing amplitude  $\delta = (E2/M1)^{1/2}$  is  $|\delta| = 1.31_{-0.18}^{+0.24}$ . The angular distribution of the resonance radiation was found to be of the form  $W(\theta) = 1 + (0.87 \pm 0.08)P_2(\cos\theta)$ . This angular distribution, together with the range of absolute values of  $\delta$  given above, fixes the sign of  $\delta$  as positive. The range of  $\delta$ -values permitted by the angular distribution measurements is  $\delta = +1.20_{-0.12}^{+0.20}$ . See also following abstract.

7358 LIFETIME OF THE 279 keV STATE OF  $\text{Tl}^{203}$ .

A.Schwarzschild and J.V.Kane.  
Phys. Rev. (USA), Vol. 122, No. 3, 854-6 (May 1, 1961).

The lifetime of the first excited state of  $\text{Tl}^{203}$  at 279 keV was measured using the delayed coincidence technique. From analysis of the exponential decay observed with an electronic time-to-pulse-height converter, the mean life was determined to be  $(4.05 \pm 0.08) \times 10^{-10}$  sec. The decay of this state was observed using sources of  $\text{Hg}^{203}$  and  $\text{Pb}^{203}$ , both sources yielding the same mean life within statistical errors. This value of the lifetime agrees very well with the determination by Deutch and Metzger (see preceding abstract) using the resonance fluorescence method.

7359 DECAY OF  $\text{W}^{183m}$ .

W.D.Schmidt-Ott, K.W.Hoffmann, I.Y.Krause and A.Flammersfeld.

Z. Phys. (Germany), Vol. 162, No. 3, 329-36 (1961). In German.  
 $\text{W}^{183m}$  was produced by the reaction  $\text{W}^{182}(n,\gamma)\text{W}^{183m}$ . The half-life was remeasured, yielding a value of  $(5.1 \pm 0.2)$  sec. With the aid of scintillation spectrometers four  $\gamma$ -lines could be detected: two lines at about 100 keV, one at  $(161 \pm 3)$  keV and one at  $(211 \pm 4)$  keV. A new technique was used to obtain the energy of the isomeric state. The total transition energy of this state was measured by summing up all possible cascade transition of  $\gamma$ -rays and conversion electrons with a source between two halves of a CsI crystal. The results are compared with the level scheme of  $\text{W}^{183}$  as measured by Murray et al. (Abstr. 4027 of 1955) in the  $\beta$ -decay of  $\text{Ta}^{183}$ . A decay scheme of  $\text{W}^{183m}$  is presented with the isomeric state at  $(310 \pm 4)$  keV and three known lower energy levels of  $\text{W}^{183}$  at 207, 99 and 46 keV. The main branch of the isomeric decay leads to the 207 keV level most probably by an M2 transition.

7360 SEARCH FOR DOUBLE  $\gamma$ -RAY EMISSION IN THE 1.75 MeV MONOPOLE TRANSITION OF  $\text{Zr}^{90}$ .

S.Gorodetzky, G.Sutter, R.Armbruster, P.Chevallier, P.Mennrath, F.Scheibling and J.Yoccoz.  
C.R. Acad. Sci. (France), Vol. 252, No. 8, 1132-4 (Feb. 20, 1961). In French.

A 200  $\mu\text{C}$   $\text{Sr}^{90}$  source was placed between two 4 in.  $\times$  4 in. NaI crystals. Fast coincidences between the two crystals were used to gate an adding circuit. Great care was necessary with background and random coincidences since only  $2 \times 10^{-4}$  of the transitions go via the 1.75 MeV level. No double  $\gamma$ -emission was detected but estimated upper limits are compared with theoretical predictions.

A.Ashmore

7361 PARTICLES OF ABNORMALLY LONG RANGE EMITTED BY POLONIUM SOURCES.

M.Morand, Y.Baudinet and L.Winand.  
Bull. Soc. Roy. Sci. Liege (Belgium), Vol. 30, No. 1-2, 11-16 (1961). In French.

Sources prepared by precipitation and also electrolytically produced one proton of range  $> 120\mu$  in nuclear emulsion ( $\sim 4$  MeV) for approximately  $10^8$   $\alpha$ 's. The possibility of an  $(\alpha,p)$  reaction in boron impurities is excluded.

E.J.Burge

7362 DELAYED NEUTRONS FROM  $\text{N}^{17}$ .

G.J.Perlow, W.J.Ramler, A.F.Stehney and J.L.Yntema.  
Phys. Rev. (USA), Vol. 122, No. 3, 899-901 (May 1, 1961).

The energies of the delayed neutrons which follow the decay of  $\text{N}^{17}$  were measured by means of a triple proportional-counter recoil spectrometer. The  $\text{N}^{17}$  was obtained from the  $\text{C}^{14}(\alpha,p)\text{N}^{17}$  reaction at a mean  $\alpha$ -particle energy of 25 MeV. Two neutron groups were observed, with energies of  $1.22 \pm 0.06$  and  $0.426 \pm 0.018$  MeV.

These correspond to neutron emission from the  $\frac{3}{2}^-$  states of  $O^{17}$  at 5.38 and 4.55 MeV, respectively. This result is consistent with the expected  $J^\pi$  of  $\frac{3}{2}^-$  for the ground state of  $N^{17}$  and with the small stripping widths for these levels in  $O^{16}(d,p)O^{17}$ . The ratio of the intensity of the high-energy group to the low-energy one is 1.6, which corresponds to a ratio of 4 for the squares of the  $\beta$ -decay matrix elements.

## NUCLEAR REACTIONS

(Including scattering by nuclei)

### 7363 SIMPLE REALISTIC TREATMENT OF NUCLEAR DIRECT-INTERACTION PROCESSES.

I.E. McCarthy and D.L. Pursey.  
Phys. Rev. (USA), Vol. 122, No. 2, 578-90 (April 15, 1961).

Physical arguments are used to predict qualitatively the effect on direct-interaction differential cross-sections of the distortion of the wave-functions of the scattered particle. These qualitative predictions are confirmed by calculations using a simple but fairly realistic model for the wave-function distortion in  $(\alpha, \alpha')$  scattering. The model used is based on examination of the properties of optical model wave-functions. Good fits to experimental data are found using the model for  $(\alpha, \alpha')$  scattering in the energy range 20-40 MeV for scattering angles less than  $90^\circ$ . Features of direct-interaction processes involving nucleons are interpreted in terms of a focus in the optical model wave-functions for these particles, but detailed calculations are not presented.

### 7364 STATISTICAL THEORY OF GAMMA-RAY SPECTRA FOLLOWING NUCLEAR REACTIONS. E.S. Troubetzkoy.

Phys. Rev. (USA), Vol. 122, No. 1, 212-17 (April 1, 1961).  
A theory predicting  $\gamma$ -ray spectra following intermediate or high-energy nuclear reactions is derived on the basis of the statistical theory. The equations take a particularly simple form if the assumption is made that all radiative transitions are of the electric dipole type. The theory is applied to two specific reactions: inelastic neutron scattering and thermal neutron capture. Numerical calculations of spectra arising from thermal neutron capture by two gadolinium isotopes are shown to compare well with experiments.

### 7365 CALCULATIONS IN NUCLEAR EVAPORATION THEORY. R. Chasman.

Phys. Rev. (USA), Vol. 122, No. 3, 902-7 (May 1, 1961).  
Methods are developed for analytic treatment of problems in nuclear evaporation theory using the level density formula  $\exp[2\{a(E^* - \epsilon)\}^{1/2}]$ . Several useful expansions are given, with their ranges of validity. Comparisons made with existing calculations indicate the validity of this approach.

## Due to Photons

### 7366 MEASUREMENT OF PHOTOPROTONS FROM ARGON AND OXYGEN. E. Finckh and U. Hegel.

Z. Phys. (Germany), Vol. 162, No. 2, 154-9 (1961). In German.  
A thin Cs I:Ti crystal was used to measure the yield of photoprotons for a 34.5 MeV bremsstrahlung spectrum. The following values relative to the yield of the  $C^{12}(\gamma, n)$  reaction were obtained:  $2.45 \pm 0.35$  for argon and  $2.06 \pm 0.28$  for oxygen. An upper limit of the integrated cross-section for the  $(\gamma, n)$ - and  $(\gamma, p)$ - reaction in oxygen is given.

### 7367 FAST PHOTO-NEUTRONS FROM BISMUTH. A. Wataghin, R.B. Costa, A.M. Freire and J. Goldenberg.

Nuovo Cimento (Italy), Vol. 19, No. 5, 864-71 (March 1, 1961).  
The energy spectrum of the photoneutrons emitted from a bismuth target irradiated with 22 MeV bremsstrahlung was studied at angles of  $30^\circ$ ,  $90^\circ$  and  $150^\circ$  to the  $\gamma$ -beam, using nuclear emulsions. An excess of high energy neutrons over the evaporation spectrum exists at all angles measured. The angular distributions can be described by the formula  $A + B \sin^2 \theta + C \cos \theta$ . The average value of the ratio  $B/A$  is  $0.68 \pm 0.15$  and the average value of  $C/A$  is  $0.155 \pm 0.056$ . The variation of  $B/A$  with energy was studied. The data indicate a maximum value of the ratio  $B/A$  around 5.5 MeV.

### PHOTOPROTONS FROM FLUORINE.

7368 B. Forkman and I. Wahlström.  
Ark. Fys. (Sweden), Vol. 18, Paper 21, 339-51 (1960).  
The results of a study of the  $(\gamma, p)$  reaction in  $F^{19}$  are presented. Thin foils of teflon were irradiated with bremsstrahlung of 15.5 and 19 MeV maximum energy. The photoprotons were recorded by nuclear emulsions. Each irradiation gives a proton spectrum containing well-resolved peaks. The peaks in the low-energy spectrum correspond to transitions from excited states in  $F^{19}$  to the ground state in  $O^{18}$ . The information about these transitions was used to analyse the high-energy spectrum. In this way it was possible to interpret the proton spectrum of the high-energy irradiation as transitions from resonances in  $F^{19}$  to the ground state and excited states in  $O^{18}$ . The observed fine structure in the  $(\gamma, p)$  absorption was compared with measurements of  $(\gamma, n)$ ; the agreement is found to be quite satisfactory. The angular distribution of the protons was measured and gives further information about the photon-absorption process.

### 7369 THE SPECTRUM OF HIGH-ENERGY PROTONS FROM THE REACTION $O^{16}(\gamma, p)N^{15}$ . U. Hegel and E. Finckh.

Z. Phys. (Germany), Vol. 162, No. 2, 142-53 (1961). In German.  
Oxygen gas was irradiated with 34.5 MeV bremsstrahlung. The spectrum of protons between 6 and 22 MeV was measured with a Na I:Ti scintillation spectrometer. The energy resolution was equivalent to that obtainable with nuclear photoplates, but the number of protons registered was much higher. The differential cross-section for  $(\gamma, p)$  reactions that leave the residual nucleus in the ground state was found to be 0.13 mbarn/steradian at 30 MeV gamma-ray energy and at  $90^\circ$  with respect to the direction of the incident beam.

PRODUCTION OF  $Co^{63}$ ,  $Ga^{75}$ , AND  $As^{81}$  FROM  $(\gamma, p)$  REACTIONS. See Abstr. 7345

## Due to Protons

ELASTIC SCATTERING OF PROTONS BY  $C^{13}$ . See Abstr. 7321

INELASTIC SCATTERING OF PROTONS BY  $C^{13}$ . See Abstr. 7325

### 7370 ELASTIC SCATTERING AND REACTIONS OF PROTONS ON $O^{18}$ .

R.R. Carlson, C.C. Kim, J.A. Jacobs and A.C.L. Barnard.  
Phys. Rev. (USA), Vol. 122, No. 2, 607-16 (April 15, 1961).  
The elastic scattering  $O^{18}(p, p)O^{18}$  and the reactions  $O^{18}(p, p'\gamma)O^{18}$ ,  $O^{18}(p, \alpha)N^{15}$ , and  $O^{18}(p, \alpha_1, \alpha_2\gamma_1, \gamma_2)N^{15}$  were studied using a thin gas target. Absolute differential cross-sections were measured for the two laboratory angles  $86.8^\circ$  and  $159.5^\circ$  in the incident proton energy range 790 to 3550 keV and angular distributions for  $\alpha_0$  and  $p$  were measured at several energies. Relative yield curves of gamma rays were obtained in the same energy range and above. Two  $F^{19}$  levels were observed which have not been previously reported and some new decay modes for previously-known levels were observed. From consideration of the detailed shape of the elastic-scattering anomalies and the angular distributions, spin and parity assignments were made to some  $F^{19}$  levels.

EXCITED STATES IN  $P^{32}$  FROM THE SCATTERING OF PROTONS BY  $Si^{28}$ . See Abstr. 7327

### 7371 YIELD MEASUREMENTS OF ALPHA PARTICLES FROM THE $^{27}Al(p, \alpha)^{24}Mg$ AND $^{31}P(p, \alpha)^{28}Si$ REACTION. J. Kuperus and P.B. Smith.

Physica (Netherlands), Vol. 26, No. 11, 954-60 (Nov., 1960).  
The yield of alpha-particles from the  $Al^{27}(p, \alpha)Mg^{24}$  and  $P^{31}(p, \alpha)Si^{28}$  reactions was measured. Of the twelve known  $Al^{27}(p, \gamma)Si^{28}$  resonances in the  $E_p = 500-850$  keV region only those at  $E_p = 504$ , 631, and 728 keV gave a detectable alpha-particle yield. Upper limits are given for the yields at the other resonance levels. Of the five  $P^{31}(p, \gamma)S^{32}$  resonance levels in  $E_p = 400-850$  keV region only that at  $E_p = 641$  keV shows detectable alpha-particle emission.

### 7372 GAMMA-RAYS FROM THE REACTION $Al^{27}(p, \gamma)Si^{28}$ . K. Okano.

J. Phys. Soc. Japan, Vol. 15, No. 1, 28-41 (Jan., 1960).  
Gamma-rays from the reaction  $Al^{27}(p, \gamma)Si^{28}$  were studied at the four resonances occurring at  $E_p = 226, 294, 326$ , and 405 keV

by the use of a large NaI crystal scintillation spectrometer. The gamma-ray transitions from the resonance states to the levels in  $^{28}\text{Si}$  at 1.78 MeV (1st), 4.62 MeV (2nd), 6.91 MeV, and 8.58 MeV were observed. Spins and parities of these levels and some of the resonance levels were deduced from the anisotropies of gamma-rays as follows: 4.62 MeV,  $J = 4(+)$ ; 6.91 MeV,  $J = 2\pm$  or  $4^+$ ; 8.58 MeV,  $J = 3^+$ ; 11.90 MeV,  $J = 4(-)$ ; 11.98 MeV,  $J = 4^-$ ,  $J = 4(+)$  for the second excited state suggests the collective nature of this excited  $\nu$  level which was expected from other evidence found in neighbouring nuclei. The gamma-ray yield and the branching ratios of each resonance level are also given.

**7373 (p,n) ANGULAR DISTRIBUTIONS FROM MIRROR NUCLEUS TARGETS:  $\text{C}^{13}$ ,  $\text{B}^{11}$ , AND  $\text{Be}^9$ .**  
R.D. Albert, S.D. Bloom and N.K. Glendenning.  
Phys. Rev. (USA), Vol. 122, No. 3, 862-9 (May 1, 1961).  
Neutron angular distributions from the (p,n) reactions in  $\text{C}^{13}$ ,  $\text{B}^{11}$ , and  $\text{Be}^9$  were measured using a long-counter detection technique in conjunction with a 90 in. variable-energy cyclotron. Proton energies ranged from threshold (2.0 to 3.2 MeV) up to 5.7 MeV. The aim was to find qualitative experimental evidence bearing on the direct reaction mechanism proposed by Bloom, Glendenning, and Moskowsky (Abstr. 13550 of 1960) wherein the (p,n) reaction connecting the ground states of mirror nuclei should go via a direct mode which is derived principally from the residual two-body interaction between the incoming proton and the bound neutron (or neutrons). It is found that the experimental evidence supports this hypothesis in that the angular distribution changes slowly in the direction of increasing complexity with increasing energy, largely ignoring the occurrence of resonances except in their immediate vicinity. Also a tentative grouping by pairs of the (p,n) angular distributions for ( $\text{C}^{13}$ ,  $\text{N}^{15}$ ) and ( $\text{Be}^9$ ,  $\text{B}^{11}$ ) shows marked similarities between the members of each pair in conformity with the twin-reaction picture stemming from the same theory. Finally, preliminary results are presented of an IBM-704 computation programme using a distorted-wave, Born approximation theory formulated originally by Glendenning (Abstr. 10092 of 1960). The comparison between theory and experiment, although based on early returns, is in general encouraging. It is found that a triplet-singlet interaction strength ratio is required which is about  $\frac{2}{3}$  of that derived from the Gammel-Thaler phenomenological potential. However, in view of the basic differences between the free and the bound two-body problem it is felt that more knowledge will be required in order properly to compare the present results with the free-scattering analyses.

**7374 (p,d) PICKUP REACTIONS IN LIGHT NUCLEI.**  
E.F. Bennett.  
Phys. Rev. (USA), Vol. 122, No. 2, 595-606 (April 15, 1961).  
Using a thin proportional counter as a velocity selector in conjunction with a NaI crystal to measure energy, deuterons from proton-induced reactions in some light nuclei were studied. The detection system was capable of presenting an essentially undistorted spectrum of deuterons in the presence of protons of the same energy and considerably more intense. Angular distributions of deuterons from  $\text{C}^{13}(\text{p,d})\text{C}^{12}$ ,  $\text{N}^{14}(\text{p,d})\text{N}^{13}$ ,  $\text{N}^{15}(\text{p,d})\text{N}^{14}$ ,  $\text{F}^{19}(\text{p,d})\text{F}^{18}$ ,  $\text{Mg}^{25}(\text{p,d})\text{Mg}^{24}$ , and  $\text{P}^{31}(\text{p,d})\text{P}^{30}$  were measured. Butler curves were calculated to fit the experimental distributions and level widths extracted.

**7375 LOW ENERGY PROTON CAPTURE RESONANCES IN THE CHLORINE ISOTOPES.** J. Kuperus.  
Physica (Netherlands), Vol. 27, No. 2, 273-6 (Feb., 1961).  
A search was made making use of natural and enriched targets. Eighteen resonances were observed in the proton energy region from 300 to 900 keV, and their isotopic assignment was established from a comparison of the yield curves. Single gamma-ray spectra were recorded at all resonances. The characteristic lines observed in the spectra confirmed the isotopic assignment, made from the yield curves. Gamma-ray yields are given in absolute measure. Branching ratios have been measured for transitions to known  $\text{A}^{36}$  and  $\text{A}^{38}$  levels.

**7376 PRODUCTION OF TRITIUM AND INERT GAS ISOTOPES BY IRRADIATING Fe AND Cu WITH 25 GeV PROTONS.**  
K. Goebel and J. Zähringer.  
Z. Naturforsch. (Germany), Vol. 16a, No. 3, 231-6 (March, 1961).  
In German.  
Production cross-sections were measured. The results do not show any essential variation compared with the results at lower energies. The He<sup>3</sup>/T ratio, measured in the same stack of targets,

is about 1.2. The cross-sections for He and T are approximately the same as at 3 GeV. The yield for the A isotopes is the same as that measured at lower energies.

**7377 INVESTIGATION OF THE REACTION  $\text{Mg}^{25}(\text{p}, \gamma)\text{Al}^{26}$ .**  
J. Muto.  
J. Phys. Soc. Japan, Vol. 15, No. 1, 17-27 (Jan., 1960).  
The  $\text{Mg}^{25}(\text{p}, \gamma)\text{Al}^{26}$  reaction was studied at the three resonances of 317, 392 and 437 keV proton energy. The level of  $\text{Al}^{26}$ , corresponding to the third excited state (3.97 MeV) in  $\text{Mg}^{26}$ , was found at  $4.18 \pm 0.02$  MeV. From the angular distributions of  $\gamma$ -rays, spins and parities of this and some other levels were assigned as follows: 3.16 MeV,  $J = 2^+$ ; 4.18 MeV,  $J = 3^+$ ; 6.61 MeV,  $J = 3^-$ ; 6.68 MeV,  $J = 2^+$  or  $3^+$ ; 6.72 MeV,  $J = 4^+$  or  $4^-$ . The second and third excited states in  $\text{Mg}^{26}$  were estimated to be  $J = 2^+$  and  $J = 3^+$  respectively. The excitation energies, the gamma decay scheme, and the radiation yield of the resonance levels are also given. The correspondence between levels of  $\text{Mg}^{26}$  and  $\text{Al}^{26}$  is discussed and a possible excited-state configuration of  $\text{Mg}^{26}$  is suggested.

**7378 MECHANISM OF THE REACTION  $\text{O}^{16} + \text{p} \rightarrow \text{p} + 4\alpha$  AT 29 MeV.** O.C. Kolar.  
Phys. Rev. (USA), Vol. 122, No. 1, 139-50 (April 1, 1961).  
An expansion cloud chamber containing oxygen gas at  $\frac{1}{2}$  atm pressure was used to study the reaction  $\text{O}^{16} + \text{p} \rightarrow \text{p} + 4\alpha$  at a bombarding energy of 28.9 MeV. 212 events were obtained that satisfied the criteria of energy and momentum balance. 91 of these had all five outgoing prongs visible, while the remaining 121 had but four prongs visible, the fifth being obscured by the beam. Slightly more than half of all the events showed the presence of the ground state of  $\text{Be}^8$ . Of these, five events showed the presence of two  $\text{Be}^8$  nuclei in the ground state. The events exhibiting the presence of a single ground-state  $\text{Be}^8$  were interpreted according to the mechanism  $\text{O}^{16} + \text{p} \rightarrow \text{p} + 2\alpha + \text{Be}^8$ ;  $\text{Be}^8 \rightarrow 2\alpha$ . The possibility of a compound state was considered. If such an intermediate state did occur, it was such that it did not obey strictly the predictions of the compound-nucleus theory. The remaining half of the events did not show evidence for any intermediate nuclei (with the possible exception of the appearance of the 1.4 MeV state of  $\text{B}^9$  in 5%, or fewer, of the cases) and could be interpreted only on the basis of the direct quadripartition of the oxygen nucleus.

**7379 ON THE RANGE OF SPALLATION PRODUCTS.**  
G. Rudstam.  
Ark. Fys. (Sweden), Vol. 18, Paper 23, 357-63 (1960).

The results of the investigation of the momentum of the spallation products in the spallation of arsenic with 170 MeV protons may be summarized as follows: (a) The range of the spallation products increases with decreasing mass number. The range distribution of any given spallation product is very wide. (b) The order of magnitude of the ranges to be expected (in arsenic) is 0.4-1.0  $\mu$ . (c) The angular distribution is sharply peaked forward in the laboratory system for all spallation products.

PROTON INTERACTIONS WITH BERYLLIUM AT 9-25 GeV/c. See Abstr. 7243

## Due to Neutrons

**7380 THE ANGULAR DISTRIBUTIONS OF NEUTRONS SCATTERED FROM VARIOUS NUCLEI.**

R.O. Lane, A.S. Langsdorf, Jr., J.E. Monahan and A.J. Elwyn.  
Ann. Phys. (USA), Vol. 12, No. 2, 135-71 (Feb., 1961).

The angular distributions of neutrons scattered from  $\text{Li}^6$  (96%),  $\text{Li}$  (normal),  $\text{Be}$ ,  $\text{C}$ ,  $\text{Si}$ ,  $\text{Ca}$ ,  $\text{Cu}$ ,  $\text{Sn}$ ,  $\text{Pb}$ , and  $\text{U}^{238}$  were measured for incident energies in the range from 50 to 2300 keV. In these measurements the energy spread of the incident neutron beam was sufficiently large to average out most of the pronounced fluctuations due to individual scattering resonances. In addition, a series of angular distributions of neutrons scattered at resonances were measured for the zero-spin nuclei  $\text{C}^{12}$ ,  $\text{O}^{16}$ ,  $\text{Si}$ , and  $\text{S}^{32}$  as well as for the isotopes  $\text{Li}^6$  and  $\text{Li}^7$ . The results are presented in terms of the least-square values of the coefficients in a Legendre-polynomial expansion of the differential scattering cross-section relative to the laboratory system of coordinates. The various corrections which have been made in order that these data represent a microscopic cross-section are discussed.

**7381 STUDIES OF GAMMA RAYS FROM NEUTRON INELASTIC SCATTERING.** D.A.Lind and R.B.Day.  
Ann. Phys. (USA), Vol. 12, No. 3, 485-532 (March, 1961).

Measurements of the gamma rays excited by neutron inelastic scattering in  $B^{11}$ , Na, Si, K, Sc, Zr, In, I, Ta, Au, Tl, and  $Pb^{208}$  were carried out by use of the conventional ring scatterer geometry within a neutron energy range from 0.2 to 3.5 MeV. The studies were used to obtain information on level structure, to determine cross-sections for gamma-ray excitation, and to make a test of the predictions of inelastic scattering cross-sections computed by a combination of the statistical and optical models. New levels and information on the decay schemes were found in Zr, I, Au, and  $Pb^{208}$ . Excitation functions in terms of absolute cross-sections are presented for the prominent gamma rays in the spectra of all the elements studied except Sc and Tl. Studies of the gamma rays from  $Pb^{208}$  gave experimental verification of the level scheme for the low spin states calculated by True and Ford. Statistical model calculations are presented which give reasonably good agreement with the experiments on  $Pb^{208}$  provided the penetrabilities are calculated using parameters obtained from an analysis of elastic scattering data specifically for  $Pb^{208}$ . The analysis shows the the imaginary part of the optical potential is abnormally low for  $Pb^{208}$  compared to that for neighbouring nuclei at comparable energies. The agreement in magnitude and shape between the experimental and calculated excitation functions can be improved if the imaginary part of the potential is permitted to increase with neutron channel energy.

**NEUTRON INELASTIC SCATTERING AND THERMAL NEUTRON CAPTURE: STATISTICAL THEORY OF  $\gamma$ -RAY SPECTRA.** See Abstr. 7364

**7382 14.4 MeV (n,2n) CROSS SECTIONS.**  
L.A.Rayburn.

Phys. Rev. (USA), Vol. 122, No. 1, 168-71 (April 1, 1961).

Cross-sections for the (n,2n) reaction were measured at an incident neutron energy of  $14.4 \pm 0.3$  MeV for 27 nuclides. These measurements were made relative to the cross-section for the  $Cu^{63}(n,2n)Cu^{62}$  reaction. The relative cross-sections were then converted to absolute cross-sections by using the weighted mean of several  $Cu^{63}(n,2n)Cu^{62}$  reaction cross-section measurements made by other investigators.

**7383 LOW-ENERGY  $\gamma$ -RAYS FROM THERMAL NEUTRON CAPTURE IN  $As^{75}$ .**

V.Cojocaru, M.Cristu, D.Dorcioman and D.Dragomirescu.  
Rev. de Physique (Roumania), Vol. 5, No. 2, 211-16 (1960).  
In French.

Neutrons from the I.F.A. reactor were moderated by 15 cm of graphite and passed through a low-energy gamma-ray filter. Gamma-rays emitted at  $90^\circ$  from the As target were detected with a 40 mm NaI crystal on an R.C.A. 6655 photomultiplier. Pulses were fed into a 20-channel pulse height analyser. Energy resolution was 15% at 480 keV. A boron filter  $0.4 \text{ g cm}^{-2}$  thick was placed in the neutron beam for background measurements. Gamma-rays were found with energies of 172, 205, 249, 311, 403 and 450 keV. Their relative intensities and the possible associated transition are given.  
A.Ashmore

**7384 AVERAGE RADIATIVE CAPTURE CROSS SECTIONS FOR 7 TO 170 keV NEUTRONS.**

J.H.Gibbons, R.L.Macklin, P.D.Miller and J.H.Neiler.  
Phys. Rev. (USA), Vol. 122, No. 1, 182-201 (April 1, 1961).

Measurements of neutron radiative capture cross-sections in the keV region were made using fast (millimicrosecond) time-of-flight techniques and a large liquid scintillator tank. Two series of measurements were completed on a number of nuclides. These are determinations of (1) cross-sections relative to that of indium at 30 and at 65 keV for 49 elements, and (2) cross-sections as a function of neutron energy for the following nuclei: Br, Nb, Pd, Ag, Cd, In, Sb, I, Pr, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ta, W, Pt, and Au. Curve fits, using the statistical model, were obtained for Br, Nb, Ag, In, Sb, I, Pr, Tb, Ho, Tm, Lu, Ta, and Au. The results demonstrate the presence of the 2p giant resonance near  $A = 100$  predicted by the optical model. The average nuclear parameters obtained are in good agreement with recent low-energy total cross-section results, but are in poor agreement with earlier results. Possible reasons for these disagreements are discussed.

**REMOVAL CROSS-SECTIONS FOR 2.9 MeV NEUTRONS.**  
V.I.Kukhtevich, B.I.Sinitin and S.G.Tsipin.

Atomnaya Energiya (USSR), Vol. 5, 565 (1958). In Russian. English translation in: Reactor Science (GB), Vol. 11, No. 11, 46-7 (Nov., 1959).

Removal cross-sections for B, C, Al, Fe, Ni, Cu, Nb and Pb have been determined for  $2.9 \pm 0.1$  MeV neutrons. The apparatus consisted of a 100 cm cube water tank. The sample (between 10 and 20 cm thick and of  $80 \times 80 \text{ cm}^2$  cross-section) and a neutron detector providing neutrons by  $D(d, n)He^3$  reaction, were placed inside the tank. The variation of cross-section per unit mass as a function of atomic weight can be expressed empirically by  $\Sigma_T/\rho = 0.385 A^{-0.688}$  for 2.9 MeV neutrons and by  $\Sigma_T/\rho = 0.21 A^{-0.688}$  for fission neutrons.  
M.Hasan

**7386 AN ANGULAR CORRELATION EXPERIMENT IN THE  $Be^9(n,2n)Be^8$  REACTION WITH 14 MeV NEUTRONS.**

H.Jeremie.  
C.R. Acad. Sci. (France), Vol. 252, No. 3, 403-4 (Jan. 16, 1961).  
In French.

The two neutrons produced in the reaction were found to be emitted preferentially in the forward direction, indicating a direct interaction mechanism.  
V.M.Ra

**7387 CARBON-13 NEUTRON TOTAL CROSS SECTION.**  
H.O.Cohn, J.K.Bair and H.B.Willard.

Phys. Rev. (USA), Vol. 122, No. 2, 534-5 (April 15, 1961).

The total neutron cross-section of  $C^{13}$  was measured for neutron energies from 110 keV to 9 MeV and from 16 to 23 MeV. Four narrow resonances were observed as well as broad resonance structure above 3 MeV. The most probable spin assignments based on the resonance heights and widths are as follows:  $E_R = 153 \pm 5$  keV,  $\Gamma = 13$  keV,  $J = 1^+$ ;  $E_R = 1751 \pm 8$  keV,  $\Gamma = 20$  keV,  $J = 1$ ;  $E_R = 2432 \pm 10$  keV,  $\Gamma = 17$  keV,  $J = 2$ ;  $E_R = 2454 \pm 10$  keV,  $\Gamma = 10$  keV,  $J \geq 1$ .

**7388 NOTE ON THE THERMAL NEUTRON CAPTURE CROSS SECTION OF  $Cs^{133}$**

A.P.Baerg and R.M.Bartholomew.  
Canad. J. Chem., Vol. 38, No. 12, 2528-31 (Dec., 1960).

The samples, along with  $Co^{59}$  monitors were irradiated in the NRX reactor. After chemical extraction, counting was done with a  $4\pi \beta-\gamma$  coincidence counter [Baerg, Bartholomew and Betts, Canad. J. Chem., Vol. 38, No. 11, 2147 (Nov., 1960)]. The method of calculating the cross-sections from the data is briefly described. The cross-section for  $Cs^{133}(n,\gamma)Cs^{134m}$  at 2200 m/sec was found to be  $2.82 \pm 0.07$  b, and for all reactions leading to the ground state of  $Cs^{134}$   $30.4 \pm 0.8$  b.  
A.Ashmore

**7389 NEUTRON CAPTURE CHAINS IN HEAVY ELEMENT SYNTHESIS.**

D.D.Clayton, W.A.Fowler, T.E.Hull and B.A.Zimmerman.  
Ann. Phys. (USA), Vol. 12, No. 3, 331-408 (March, 1961).

This paper is concerned with stellar neutron capture processes which occur at a rate slow compared to the intervening beta decays, the so-called s-process in the synthesis of the elements. An approximate method of high reliability has been devised to solve for the abundance distributions resulting from the exposure of seed nuclei, such as  $Fe^{56}$ , to a weak neutron flux in stars. The capture chain differential equations are solved by approximately matching the Laplace transforms of the exact solutions to the Laplace transform of an easily calculable function. From the sequence of abundance distributions generated in this manner for specified numbers of neutrons per initial seed nucleus, one can estimate the superpositions of neutron exposures required to reproduce the experimentally observed abundance distribution for the s-process isotopes of the elements. Not only can the validity of the s-process model of heavy element synthesis in stellar interiors be demonstrated in this way, but certain inferences about the "history" of stellar neutron processes also appear. Special attention is paid in this regard to the "terminal" exposures which have synthesized lead and bismuth at the end of the line in the s-process. An analysis is appended of neutron capture cross-sections near 25 keV for the s-process nuclei, including interpolations based upon empirical cross-sections guided where necessary by isotopic and elemental abundances. A complete correlation between neutron capture cross-sections and s-process abundances cannot be made at the present stage of knowledge, but the methods described will lead to an eventual solution as more empirical information becomes available.

# 7390 NEW ISOTOPE OF MANGANESE; CROSS SECTIONS OF THE IRON ISOTOPES FOR 14.8 MeV NEUTRONS.

D.M.Chittenden, II, D.G.Gardner and R.W.Fink.

Phys. Rev. (USA), Vol. 122, No. 3, 860-1 (May 1, 1961).

Bombardment of iron enriched in  $\text{Fe}^{58}$  with 14.8 MeV neutrons produces an activity having a half-life of  $1.1 \pm 0.1$  min. On the basis of cross-bombardments and the gamma-ray spectrum of the activity, this is assigned to  $\text{Mn}^{58}$ . In addition, the following cross-sections were measured:  $\text{Fe}^{56}(\text{n,p})$ ,  $23.0 \pm 3.5$  mb;  $\text{Fe}^{57}(\text{n,p})$ ,  $71.0 \pm 7.0$  mb;  $\text{Fe}^{58}(\text{n,p})$ ,  $128 \pm 13$  mb;  $\text{Fe}^{58}(\text{n},\alpha)$ ,  $21.5 \pm 2.0$  mb;  $\text{Fe}^{54}(\text{n},\alpha)$ ,  $270 \pm 135$  mb;  $\text{Fe}^{57}(\text{n,np})$ ,  $6.1 \pm 2.6$  mb;  $\text{Fe}^{54}(\text{n},2\text{n})$ ,  $7.9 \pm 0.8$  mb;  $\text{Fe}^{54}(\text{n,t})$ ,  $0.6 \pm 0.1$  mb.

# 7391 SEARCH FOR THE (n, t) REACTION AT 14 MeV IN SOME MEDIUM WEIGHT NUCLEI.

A.P.Baerg and G.C.Bowes.

Canad. J. Chem., Vol. 39, No. 3, 684-8 (March, 1961).

This reaction (at 14.6 MeV) was observed to occur in  $\text{S}^{32}$  with a cross-section of  $4 \pm 1$  microbarns. Upper limits for the cross-section of this reaction are also given for  $\text{Ca}^{40}$ ,  $\text{Cr}^{50}$ ,  $\text{Fe}^{54}$  and  $\text{Zn}^{64}$ . The results are discussed qualitatively in the light of recently reported (n, He<sup>3</sup>) reactions (Abstr. 7610 of 1960).

# 7392 THE RADIATIVE CAPTURE OF A NEUTRON BY Sc, Fe, Cu, Mo, Cd AND La NUCLEI.

J.Urbancic, J.Kajfosz and J.Kopecký.

Czech. J. Phys., Vol. 10, No. 4, 275-83 (1960). In Russian.

The energies and intensities of the transitions of a compound nucleus, produced by the capture of a neutron, were measured by means of a single-crystal scintillation spectrometer. Measurements on Sc, Fe, Cu, Mo, Cd and La nuclei were made in the region of energies 20-1000 keV.

# 7393 $\text{Th}^{232}(\text{n}, 2\text{n})\text{Th}^{231}$ CROSS SECTION FROM THRESHOLD TO 20.4 MeV. J.P.Butler and D.C.Santry.

Canad. J. Chem., Vol. 39, No. 3, 689-96 (March, 1961).

The excitation curve for this reaction was measured by the activation method from the threshold energy (6.34 MeV) to 20.4 MeV, relative to the known cross-section for the  $\text{S}^{32}(\text{n}, \text{p})\text{P}^{32}$  reaction. Monoenergetic neutrons were obtained from the  $\text{D}(\text{d}, \text{n})\text{He}^3$  and  $\text{T}(\text{d}, \text{n})\text{He}^4$  reactions employing a tandem Van de Graaff accelerator. From threshold to 9.0 MeV, the (n, 2n) cross-section rises rapidly, reaching its maximum value of  $1.88 \pm 0.09$  barns in the region of 9.5 to 11.0 MeV. Above 11.5 MeV, the (n, 2n) cross-section decreases due to competition of the (n, 3n) and (n, 2nf) reactions, and at 20.4 MeV it has a value of  $0.22_{\pm} \pm 0.01_{\pm}$  barns.

## Due to Mesons and Hyperons

# 7394 $\pi^-$ SCATTERING FROM COMPLEX NUCLEI.

R.M.Edelstein, W.F.Baker and J.Rainwater.

Phys. Rev. (USA), Vol. 122, No. 1, 252-61 (April 1, 1961).

Differential cross-sections were measured for  $\pi^-$ -carbon scattering at 69.5 and 87.5 MeV and  $\pi^-$ -oxygen scattering at 87.5 MeV from  $20^\circ$  to  $125^\circ$ , extending the technique of Baker et al. (Abstr. 3928 of 1959). The energy resolution was sufficient to measure pure elastic cross-sections as well as 5 and 10 MeV inelastic cross-sections. The modified Kisslinger optical model equation was used to fit the elastic cross-section data. A  $\chi^2$  analysis for the 69.5 MeV carbon data gave a nuclear radius parameter  $r_0 = 1.05 \pm 0.02$  fermis and a fall-off parameter  $t = 1.16 \pm 0.07$  fermis. These parameters give good fits to the other data as well. An energy dependence in the strength parameters for carbon is observed in qualitative agreement with prediction.

# SCATTERING OF 2 BeV/c MUONS IN CARBON AND LEAD.

See Abstr. 7257

# 7395 ON THE NUCLEAR CAPTURE OF MUONS WITH ELECTRON EMISSION.

M.Conversi, L.di Lella, A.Egidi, C.Rubbia and M.Toller.

Phys. Rev. (USA), Vol. 122, No. 2, 687-95 (April 15, 1961).

Two experiments carried out to search for the process of muon capture with electron emission are reported. The second of the two experiments is nearly 200 times more sensitive than earlier attempts to find this capture mode, but no indication is obtained in favour of the latter. In both experiments negative muons are made to stop in copper, where coherent capture is predominant, so that the "capture electrons" should be emitted with an energy spectrum sharply

peaked around 100 MeV. For the branching ratio of the process searched for, relative to ordinary muon capture, upper limits of about  $5 \times 10^{-5}$  and  $5 \times 10^{-6}$  are established through the first and second experiment, respectively.

## Due to Deuterons

# 7396 INELASTIC SCATTERING OF DEUTERONS FROM THE MAGNESIUM ISOTOPES. A.G.Blair and E.W.Hamburger.

Phys. Rev. (USA), Vol. 122, No. 2, 566-71 (April 15, 1961).

Natural and enriched magnesium targets were bombarded with 15 MeV deuterons from a cyclotron. The reaction products were magnetically analysed and detected by a scintillator or by nuclear emulsions. Angular distributions were obtained for the deuterons inelastically scattered from the  $\text{Mg}^{24}$  1.37 MeV,  $\text{Mg}^{25}$  1.61 MeV, and  $\text{Mg}^{26}$  1.83 MeV states. The results are compared to the predictions of the plane-wave Born approximation theory and of the inelastic diffraction scattering model. The curves obtained from the Born approximation give better over-all correspondence with the experimental points. The inelastic diffraction scattering model, however, allows one to extract directly the effective values of the nuclear deformation parameter  $\beta$ . One obtains  $|\beta| = 0.20, 1.19$  and  $1.17$  for  $\text{Mg}^{24}$ ,  $\text{Mg}^{25}$  and  $\text{Mg}^{26}$ , respectively. The spectra of deuterons inelastically scattered from  $\text{Mg}^{25}$  and  $\text{Mg}^{26}$  were also observed at  $\theta_{\text{lab}} \approx 12^\circ, 30^\circ$ , and  $60^\circ$ . The only large cross-sections in  $\text{Mg}^{25}$  were those for the 1.61 MeV ( $\frac{7}{2}^+$ ) level and for a level near 3.4 MeV. The strength of the reaction to the latter level suggests that it is the  $\frac{5}{2}^+$  member of the ground-state rotational band which, in analogy with  $\text{Al}^{25}$ , should appear at approximately this energy. The results tend to confirm the selection rule that favours collective excitations over single-particle excitation in inelastic scattering. In  $\text{Mg}^{26}$  strong scattering was observed only from the first two excited states. A previously unreported  $\text{Mg}^{26}$  state was found at the excitation energy of  $3.614 \pm 0.020$  MeV.

# 7397 ON THE (d, $\alpha$ ) REACTIONS.

M.El-Nadi and M.Wafik.

Proc. Math. Phys. Soc. UAR (Egypt), No. 23, 117-23 (June, 1959).

The differential cross-section for the (d,  $\alpha$ ) reaction is given together with the effect of the nuclear radius and the form of the wave-function of the  $\alpha$ -particle on the shape of the angular distribution.

# 7398 LOW-LYING ENERGY STATES IN $\text{Ne}^{20}$ FROM THE $\text{F}^{19}(\text{d}, \text{n})\text{Ne}^{20}$ REACTION.

R.E.Benenson, H.Y.Chen and L.J.Lidofsky.

Phys. Rev. (USA), Vol. 122, No. 3, 874-8 (May 1, 1961).

Six neutron groups from the  $\text{F}^{19}(\text{d}, \text{n})\text{Ne}^{20}$  reaction corresponding to the lowest state in  $\text{Ne}^{20}$  observed at six angles of observation. The major part of the experiment employed nuclear emulsions and an average deuteron energy of 3.57 MeV. The importance of stripping appears to depend on the particular level involved; in particular, angular distributions leading to unambiguous assignments by stripping theory appear only for the ground, 1.63 MeV, and 6.75 MeV levels. The ground-state assignment appears to be energy dependent when the present  $l_p = 2$  value is compared to the  $l_p = 0$  value previously reported for a higher bombarding energy. The 4.25 MeV level in  $\text{Ne}^{20}$  gives rise to an angular distribution which could be either  $l_p = 2$  or  $l_p = 3$ , but the fit to theory is not satisfactory for either case. A qualitative argument is given favouring the latter value. No assignment can be made to the 4.97 and 5.63 MeV levels. A brief second experiment with a fast neutron spectrometer was performed in order to obtain an absolute differential cross-section at  $0^\circ$  for  $\text{Ne}^{20}$  left in its 6.75 MeV level. The reduced width obtained from this cross-section is compared with a published reduced width for this same level obtained by elastic scattering of alpha particles by  $\text{O}^{16}$ .

# 7399 ANALYSIS OF SOME DEUTERON-INDUCED REACTIONS IN OXYGEN-18.

J.C.Armstrong and K.S.Quisenberry.

Phys. Rev. (USA), Vol. 122, No. 1, 150-63 (April 1, 1961).

The reactions  $\text{O}^{18}(\text{d}, \text{t})\text{O}^{17}$ ,  $\text{O}^{18}(\text{d}, \text{d}')\text{O}^{18*}$ , and  $\text{O}^{18}(\text{d}, \text{p})\text{O}^{19}$  were studied using 15 MeV deuterons and magnetic analysis of reaction particles. Absolute cross-sections were determined for all reactions studied and the Butler-Born approximation is used to extract reduced widths when possible. Angular distributions of triton groups corresponding to the ground, 0.871, 3.846, 4.555, 5.083, and 5.378

MeV states of  $O^{17}$  are obtained. An estimate of the configuration admixtures in the  $O^{18}$  ground state is made from analysis of the reduced widths and indicates the presence of a sizable (about 6%) ( $17/2^+$ ) component. The experimentally determined admixtures are compared with several theoretical estimates. All  $O^{18}$  levels observed in the inelastic deuteron scattering have been previously reported — the known 5.01 MeV state is not observed. The angular distribution of inelastic deuterons corresponding to the 1.982 MeV state of  $O^{18}$  is obtained and comparison of the absolute cross-section with theory provides an estimate of the  $O^{18}$  deformation. Proton groups from  $O^{18}(d,p)O^{19}$  reactions are observed corresponding to  $O^{19}$  excitations of 0, 1.469, 3.164, 3.948, (4.123), (4.586), (4.706), (5.165), 5.45, 5.707, and 6.279 MeV, where assignment of the levels in parentheses to  $O^{19}$  is uncertain. The known 0.096 MeV state is not observed and the proton group corresponding to 5.45 MeV excitation contains contributions from at least two states. Angular distributions leading to the  $O^{19}$  ground, 1.469, 3.164, 3.948, 5.707, and 6.279 MeV states are obtained and reduced widths extracted. The  $I_n$  values for these angular distributions are ambiguous except for the ground-state reaction ( $I_n = 2$ ) and the 1.469 MeV state reaction ( $I_n = 0$ ). Analysis of the data suggests that  $J\pi$  (ground state) =  $\frac{3}{2}^+$  and  $J\pi$  (0.096 MeV state) =  $\frac{3}{2}^+$ . Using parameter values estimated from the  $O^{19}$  energy level spectrum or obtained from neighbouring nuclei, a description of this nucleus in terms of the strong-coupling unified model agrees with the data.

**STUDY OF THE 6.33 MeV LEVEL IN  $N^{15}$  BY THE REACTION  $N^{14}(d,p)N^{15}$ .** See Abstr. 7326

7400  $Si^{28}(d,p)Si^{29}$  REACTION.  
A.G.Blair and K.S.Quisenberry.  
Phys. Rev. (USA), Vol. 122, No. 3, 869-73 (May 1, 1961).

The 15 MeV deuteron beam from a cyclotron was used to study the  $Si^{28}(d,p)Si^{29}$  reaction. Angular distributions of protons from most of the  $Si^{29}$  levels up to an excitation energy of 6.4 MeV were obtained. Good agreement with the 8 MeV deuteron results of Holt and Marsham (Abstr. 7126 of 1953) was found, except in a few cases where an  $l = 2$  distribution showed low-angle peaking in one of the experiments but not in the other. The angular distributions of the 5.94 and 6.19 MeV states in  $Si^{29}$ , not previously reported, were obtained. Butler curves with  $l = 2$  and  $l = 3$ , respectively, were fitted to those two distributions. A somewhat unusual evaporation technique, used to prepare the necessary targets from small quantities of  $SiO_2$  with relatively high collection efficiency, is described.

## Due to Alpha-particles

7401 APPARATUS DRAWINGS PROJECT. REPORT NUMBER 16. APPARATUS FOR MEASURING THE RUTHERFORD SCATTERING OF ALPHA PARTICLES BY THIN METAL FOILS.  
R.G.Marclay.  
Amer. J. Phys., Vol. 29, No. 6, 349-54 (June, 1961).

An evacuated metal cylinder houses a movable system containing the alpha-particle emitter, a small 0.1 mc  $Po^{210}$  welded-foil source, and, at a fixed distance from this source, an annular ring of scattering material. The face of a type 5819 photomultiplier serves to seal the end of the vacuum chamber, and has at its centre the detector, a small circular spot of  $ZnS:Ag$  scintillator. The source, scatterer, and detector are coaxial. The scattering angle may be varied between  $28^\circ$  and  $71^\circ$  by changing the distance from the scattering annulus to the detector, with a resultant change in the counting rate from about 30/min and 4/min. Range and intensity measurements on the source are easily made. If common sense precautions are taken, no radiation hazards will be encountered.

7402 STUDY OF THE INELASTIC SCATTERING OF 44 MeV  $\alpha$ -PARTICLES BY CALCIUM 40. J.Saudinos, R.Beurtrey, P.Catillon, R.Chaminade, M.Crut, H.Faraggi, A.Papineau and J.Thirion.  
C.R. Acad. Sci. (France), Vol. 252, No. 2, 260-2 (Jan. 9, 1961). In French.

Differential cross-sections for inelastic scattering of  $\alpha$ -particles on  $Ca^{40}$  were obtained. Levels at 3.78, 4.47, 6.16 and 6.74 MeV were excited. Theoretical analysis of the data shows that all these levels have odd parity, and levels known to have even parity are not excited. This supports Brown's hypothesis that odd-parity levels should be preferentially excited. D.J.Thouless

7403 MULTIPOLE COLLECTIVE EXCITATION IN SEVERAL ODD NUCLEI FROM INELASTIC SCATTERING OF  $\alpha$ -PARTICLES. J.Saudinos, R.Beurtrey, P.Catillon, R.Chaminade, M.Crut, H.Faraggi, A.Papineau and J.Thirion.  
C.R. Acad. Sci. (France), Vol. 252, No. 1, 96-8 (Jan. 4, 1961). In French.

Alpha-particle spectra were obtained with an analysing magnet with a resolution of 0.6% in energy, for the bombardment of  $Cu^{63}$ ,  $Cu^{65}$ ,  $Fe^{57}$ . The results are interpreted in terms of a single-particle excitation coupled to collective motion of the core. A.Ashm

7404 ELASTIC SCATTERING OF ALPHA PARTICLES BY  $N^{15}$ .

H.Smotrich, K.W.Jones, L.C.McDermott and R.E.Benenson.  
Phys. Rev. (USA), Vol. 122, No. 1, 232-41 (April 1, 1961).

Absolute differential cross-sections for the elastic scattering of alpha-particles by  $N^{15}$  were measured in a differentially-pumped gas scattering chamber. The measurements were made at centre-of-mass angles of 169.1, 149.5, 140.8, 125.3, 90.0, and 70.0 degrees for alpha-particle energies from 1.75 to 5.50 MeV, corresponding to 5.37 to 8.33 MeV excitation of the compound nucleus  $F^{18}$ . The experimental widths of the levels observed below approximately 3.5 MeV bombarding energy are generally narrow, in most cases less than 10 keV. Above 3.5 MeV a marked increase in the level width was observed. As a result of an analysis based on the Wigner-Eisenbud reaction theory, values of  $J$ ,  $\pi$ ,  $E_\lambda$ , and  $\gamma_\lambda^2$  were assigned to 16 levels in  $F^{18}$ .

$Si^{28}(He^3,n)S^{30}$  REACTION. See Abstr. 7336

GAMMA RAYS FROM  $O^{16}(He^3,p)F^{18}$ . See Abstr. 7323

## Nuclear Fission

7405 THE THERMAL NEUTRON FISSION YIELDS OF  $U^{233}$ .  
D.R.Bidinosti, D.E.Irish and R.H.Tomlinson.  
Canad. J. Chem., Vol. 39, No. 3, 628-34 (March, 1961).

Using a mass spectrometer and isotope dilution technique, 27 cumulative fission yields from the thermal neutron fission of  $U^{233}$  along with 13 other fission product chains relative to each other have been determined. After normalization of the latter, values obtained for all but seven fission decay chains whose yields are in excess of 0.5%.

7406 THE FISSION CROSS-SECTIONS OF  $U^{233}$  AND THE TOTAL EFFECTIVE CROSS-SECTIONS OF As, V, Te AND Bi.

V.V.Vladimirskii, A.A.Panov, I.A.Radkevich and V.V.Sokolovskii.  
Atomnaya Energiya (USSR), Vol. 5, No. 1, 69-70 (1958). In Russian. English translation in: Reactor Science (GB), Vol. 10, No. 1-2, 64-5 (July, 1959).

Using a mechanical chopper neutron spectrometer the fission cross-section of  $U^{233}$  and the total cross-sections of arsenic, vanadium, tantalum and bismuth were measured and the various observed levels investigated. G.J.Ba

7407 NUCLEAR EMULSION STUDY OF THE TERNARY FISSION OF  $U^{235}$  BOMBARDED WITH THERMAL NEUTRONS. J.Català, V.Domingo and J.Casanova.  
Nuovo Cimento (Italy), Vol. 19, No. 5, 923-8 (March 1, 1961). In Spanish.

The results are presented of a study of 1000 fission events in  $U^{235}$  in which a light particle was emitted. Because of the large number of events analysed, it was possible to obtain data of good statistical accuracy on the frequency of emission of light particles on their angular distribution and the upper limit of their energy spectrum. Also determined were the mean ranges, masses and energies of the light particles and of the heavy fragments.

7408 THE YIELDS OF  $Sr^{90}$  AND  $Sr^{88}$  IN THE FISSION OF  $Pu^{239}$  BY PILE NEUTRONS.

L.M.Krizhansky and A.N.Murin.  
Atomnaya Energiya (USSR), Vol. 4, No. 1, 80 (1958). In Russian. English translation in: Reactor Science (GB), Vol. 10, No. 3-4, 163-4 (Sept., 1959).

A mass spectrometric determination was made of the yields of  $Sr^{90}$  and  $Sr^{88}$  in a sample of  $Pu^{239}$  which had been subjected to a total flux of  $2.7 \times 10^{20}$  neutrons/cm<sup>2</sup>. Absolute values were obtained by the method of isotopic dilution. S.J.Golds

- 7409 ON THE THEORY OF NUCLEAR FISSION. II-III.  
W. Brunner and H. Paul.  
Ann. Phys. (Germany), Vol. 7, No. 5-6, 326-32, 333-41 (1961).  
In German.

For Pt I, see Abstr. 4878 of 1961. The total excitation energy of the fission fragments, in the fission of  $U^{235}$  by thermal neutrons, is calculated using the experimental data on the mean kinetic energy of the fragments, together with energy conservation and the Fong mass formula. The dependence of the deformation of the fragments on this energy is determined by assuming that it is divided between the two fragments in proportion to their masses. Strong effects of closed neutron shells are observed. In Pt III the theory developed by the authors, to take account of the interaction between the two fragments, is used to estimate the dependence of this interaction on the mass ratio of the fragments and on their deformations. The results agree well with those obtained by alternative considerations.

E.J. Squires

## Thermonuclear Reactions

- 7410 ON THE YIELD OF THERMONUCLEAR [D-D] REACTIONS. V.I. Kogan.  
Plasma physics", Vol. II (see Abstr. 5439 of 1961) p. 165-96.  
Considers: (1) the range of validity of the simple analytic expression for the yield (the Bethe-Atkinson formula); (2) the effect of cutting off the tail of the Maxwell distribution of ionic velocities; (3) the most favourable number of particles (for given input energy), given a polytropic law of contraction for the reacting plasma; (4) the most favourable number of particles (for a given current) in a plasma current system operating in the region of similar solutions taking into account the temperature difference between ions and electrons).
- 7411 CALCULATION OF  $\langle \sigma v \rangle$  COEFFICIENTS APPEARING IN THERMONUCLEAR REACTION RATES.  
D. Magnac-Valette, M. Monnier, P. Caffier and P. Cüer.  
Phys. Radium (France), Vol. 21, No. 3, 199-200 (March, 1960).  
In French.  
Since discrepancies have appeared between different authors, calculations of  $\langle \sigma v \rangle$  using recent experimental values of  $\sigma$  are made. New values are given also for different temperature conditions.

## NUCLEAR POWER STUDIES

- 7412 THE ORGANIC REACTOR AND THE URANIUM-THORIUM CYCLE PROGRAMMES OF C.N.E.N.  
F. Ippolito, A. Cacciari and A. Forcella.  
Energia nucleare (Italy), Vol. 8, No. 3, 196-208 (March, 1961).  
In Italian.  
Two major research and development programmes (P.R.O. and P.C.U.T.) to be carried out by C.N.E.N. are described. The organic reactor programme (P.R.O.) involves the realization of a 10 MwT organic moderated and cooled reactor, in close cooperation with the U.S. Atomic Energy Commission, and research and development work. The uranium-thorium cycle programme (P.C.U.T.) foresees the realization of an uranium-thorium reprocessing pilot plant, in which fuel elements from the Elk River reactor will be treated: its aim is to study the uranium-thorium cycle having in view a power reactor-reprocessing plant integrated complex.
- 7413 ON THE SPATIAL VARIATION OF THE NEUTRON SPECTRUM IN A HETEROGENEOUS REACTOR, MODERATED AND COOLED WITH NATURAL WATER.  
P. Purica, R. Ștefănescu and M. Sabău.  
Rev. de Physique (Roumania), Vol. 5, No. 2, 189-98 (1960).  
In French.  
A study has been made, at Bucarest, of the spectrum in such a

reactor, with 10% enriched uranium. The temperature of the thermal neutrons was measured by observing reactivity changes produced by the insertion of wires and foils of cadmium and boron. The spatial variation of the thermal, epithermal and fast-neutron spectra was determined by measuring the  $\beta$ -activity of irradiated probes of gold, indium, copper and aluminium. These measurements also give the constant B and the distortion of the Fermi distribution of the epithermal neutrons.

D.H. Lord

- NON-LINEAR KINETICS AND STABILITY STUDIES  
7414 ON ANALOG COMPUTER. H.A. Sandmeier.  
Nuclear Electronics Conference, Paris, 1958, Vol. II, (see Abstr. 12720 of 1960) p. 39-55.

A schematic diagram of a simulator for a fast power reactor is given, and the results of tests with sinusoidal and step function (rod dropping) changes of reactivity are compared with analytical solutions. The amplitude of oscillations depends on the power level and on the rod bowing limit. For constant bowing limit the amplitude decreases with increasing power. For constant power the amplitude increases with increasing bowing limit.

W.G. Stripp

- THE BACKGROUND NOISE OF NUCLEAR REACTORS.  
7415 A SIMPLE ELECTRIC MODEL.  
A. Blaquièrre and R. Paçhowska.  
C.R. Acad. Sci. (France), Vol. 251, No. 25, 2918-20 (Dec. 19, 1960).  
In French.

The expressions for the long- and short-period noise in a nuclear reactor are reduced, by a perturbation method, to equations analogous to those of resistance and capacitance electric circuits. Using the known solutions to these problems, the mean square of the density fluctuations and the frequency spectrum of the noise may be calculated.

J.E. Gore

- THE COMPUTATION OF THE FERMI AGE IN A HETEROGENEOUS REACTOR BY THE MONTE CARLO METHOD. W. Matthes and T. Springer.  
Reactor Science (GB), Vol. 10, No. 3-4, 158-60 (Sept., 1959).

The Fermi age for a series of lattices of different uranium-to-water ratios and different uranium rod sizes is calculated by the Monte Carlo method, using about 800 paths for each case. The results are compared with the available experimental information and agreement between the two is shown to be good.

J.P. Hill

- NUMERICAL CONTROL OF THE DETECTION OF  
7417 SHEATH RUPTURE. J. Gaudferneau.  
Nuclear Electronics Conference, Paris, 1958, Vol. II, (see Abstr. 12720 of 1960) p. 277-82. In French.

In the system described, measurements of activity in groups of channels are stored and then analysed by a computer.

W.G. Stripp

- HEAVY-WATER MODERATED REACTORS COOLED  
7418 BY LIGHT STEAM-WATER MIXTURES. M. Silvestri.  
Energia nucleare (Italy), Vol. 8, No. 3, 209-12 (March, 1961).  
In Italian.

Qualitative considerations on the general economy of heavy-water-moderated, natural-uranium-fuelled reactors, show how important the choice of the coolant is. A light steam-water mixture cooling seems to be most promising, because such a coolant is a very good approximation to an ideal one: the problems involved in the understanding of some basic phenomena are reviewed, with particular emphasis on heat-transfer, hydrodynamics, corrosion and erosion problems.

- THERMONUCLEAR REACTIONS IN A SYSTEM WITH  
7419 MAGNETIC STOPPERS [MIRRORS] AND THE PROBLEM OF DIRECT TRANSFORMATION OF THERMONUCLEAR ENERGY INTO ELECTRICAL ENERGY. G.I. Budker.  
"Plasma physics", Vol. III (see Abstr. 5439 of 1961) p. 1-33.

The basic physical principles and preliminary calculations are given for a method of producing thermonuclear reactions in a straight cylinder closed by magnetic mirrors. A method is considered for initiating the discharge in a high vacuum and heating the plasma by means of a "magnetic piston". The direct conversion of nuclear energy into electric energy is also discussed.

# ATOMIC AND MOLECULAR PHYSICS

7420 ABSOLUTE DEFINITION OF PHASE SHIFT IN THE ELASTIC SCATTERING OF A PARTICLE FROM COMPOUND SYSTEMS. A. Temkin.

J. math. Phys. (New York), Vol. 2, No. 3, 336-40 (May-June, 1961).  
The projection of the target wave-function on the total wave-function of a scattered particle interacting with the target system is used to define an absolute phase shift including any multiples of  $\pi$ . With this definition of the absolute phase shift, one can prove rigorously in the limit of zero energy for s-wave electrons scattered from atomic hydrogen that the triplet phase shift must approach a non-zero multiple of  $\pi$ . One can further show that at least one  $\pi$  of this phase shift is not connected with the existence of a bound state of the  $H^+$  ion.

7421 ANALYTICAL METHODS IN HARTREE-FOCK SELF-CONSISTENT FIELD THEORY. S. Huzinaga.

Phys. Rev. (USA), Vol. 122, No. 1, 131-8 (April 1, 1961).  
For previous work, see Abstr. 20675 of 1960. Two alternative schemes are proposed for the determination of electronic self-consistent field (SCF) orbitals in atoms and molecules. They are designed to be applied principally to electronic configurations consisting of two open shells. Both schemes are based upon the idea that the SCF orbitals are expanded in terms of adequate basis functions but they are different in the way of solving the SCF problem. An attempt is made to rate the relative merits of both schemes, though they have not yet received any actual application.

7422 VARIATION-PERTURBATION METHOD FOR EXCITED STATES. O. Sinanoğlu.

Phys. Rev. (USA), Vol. 122, No. 2, 491-2 (April 15, 1961).  
The first-order wave-function,  $X_1$ , in the perturbation method can be obtained by a variational principle instead of summing the usual infinite series with a large continuum contribution. For a ground state or the lowest state of a given symmetry, suitable trial functions,  $\tilde{X}_1$ , are chosen to attain  $E_2$ , the second-order contribution to the energy, as a minimum. This method is extended here to any excited state,  $m$ , regardless of its symmetry. To obtain  $X_1^m$ , the expression

$$\tilde{E}_2^m = \{2\langle\Phi_0^m, (H_1 - E_1^m)\tilde{X}_1^m\rangle + \langle\tilde{X}_1^m, (H_0 - E_0^m)\tilde{X}_1^m\rangle\} \geq E_2^m,$$

is to be minimized with  $\tilde{X}_1^m$  in the form

$$\tilde{X}_1^m = \bar{X}_1^m + \sum_{k=0}^{m-1} \frac{\Phi_0^k \langle\Phi_0^k, H_1 \Phi_0^m\rangle}{E_0^m - E_0^k},$$

with  $\bar{X}_1^m$  orthogonal to the known unperturbed functions of the states lower than  $m$ . The  $X_1$  gives also the third-order energy. The method may be applied to such excited states as  $(1s2s)^1S$  of He-like ions and to the similar electron pairs that arise in the author's theory of a many-electron atom or molecule (see following abstract).

7423 PERTURBATION THEORY OF MANY-ELECTRON ATOMS AND MOLECULES. O. Sinanoğlu.

Phys. Rev. (USA), Vol. 122, No. 2, 493-9 (April 15, 1961).  
Perturbation theory with operator techniques is applied to a non-degenerate many-electron system taking the entire electron-electron repulsions,

$$\sum_i > j r_{ij}^{-1},$$

as the perturbation. The first-order wave-function,  $X_1$ , is obtained rigorously in terms of the first-order wave-functions of independent two-electron systems. The wave-functions of these electron pairs contain nuclear parameters and can be obtained individually by variational or other methods, then used in various atoms or molecules. For example Li atom is built up completely from the  $(1s)^2^1S$ ,  $(1s2s)^1S$  and  $^3S$  states of  $Li^+$ . The  $X_1$  gives the energy to third order and as an upper limit to the exact  $E$ . The  $E_2$  is equal to the sum of complete pair interactions plus many-body terms of two types: (a) "cross polarization", which exists even in no-exchange intermolecular forces, and (b) Fermi correlations.

ANTISHIELDING OF NUCLEAR ELECTRIC HEXA-DECAPOLE MOMENTS. R.M. Sternheimer.

Phys. Rev. Letters (USA), Vol. 6, No. 4, 190-2 (Feb. 15, 1961).  
Presents calculations of the hexadecapole moments (HDM) induced in the closed electron shells of ions by the nuclear HDM which show that antishielding effects may make possible the measurement of the nuclear HDM in quadrupole resonance spectra using ions in crystals or polar molecules. J. Hawley

## ATOMS

7425 FREE PROPAGATOR EXPANSION IN THE EVALUATION OF THE LAMB SHIFT. I. A.J. Layzer.

J. math. Phys. (USA), Vol. 2, No. 3, 292-307 (May-June, 1961).  
This is the first of two papers concerned with "order properties" with respect to the parameter  $\alpha Z$ , of an expansion method for the evaluation of the bound electron self-energy  $\Delta E$  and the application of these properties to the calculation of the new Lamb shift order of  $\alpha(\alpha Z)^8 \ln^2(\alpha Z)$  and  $\alpha(\alpha Z)^6 \ln(\alpha Z)$ . The expansion method is the free-propagator expansion (FPE); that is, the formal algebraic expansion of the bound electron propagator or Green's function in "powers" of the external (Coulomb) potential. The principal result of the general mathematical analysis is a theorem which asserts that the FPE is an order expansion for (only) those terms of  $\Delta E$  that are non-analytic in the parameter  $w \equiv (\alpha Z)^2$  and is thus particularly suitable for the calculation of this class of terms. A practical result of the theorem is that the new logarithmic orders arise from only the first four terms of the FPE. The non-analytic part of a fixed term  $I_n$  of the FPE can be attacked directly through a consideration of  $\text{Im} I_n$ , where  $\text{Im} I_n$  denotes the imaginary part of  $I_n$ , regarded as a function of the complex variable  $w$ , on the upper side of a branch cut along the negative  $w$  axis. As an auxiliary result, boundedness properties in momentum space are derived for certain integral operators related to the FPE of the bound nonrelativistic electron Green's function. See also following abstract.

7426 FREE PROPAGATOR EXPANSION IN THE EVALUATION OF THE LAMB SHIFT. II. A.J. Layzer.

J. math. Phys. (USA), Vol. 2, No. 3, 308-23 (May-June, 1961).  
The results of the preceding paper (see preceding abstract) are extended and applied to the calculation of the new Lamb shift order of  $\alpha w^3 \ln^2 w$  and  $\alpha w^3 \ln w [w \equiv (\alpha Z)^2]$ . The final result for the  $2S-2P$  shift due to the  $\ln^2$  and  $\ln$  terms, which has been previously published is  $\Delta E(2S-2P_{1/2}) = -Lw^{3/4} \ln^2 w + \ln w (4 \ln 2 + 1 + 7/48)$  where  $L$  is 2 times the Lamb unit. In megacycles this is  $-0.25$  for H and  $-0.9$  for  $He^+$ . The corresponding new values for the total theoretical shift are  $1057.70 \pm 0.15$ ,  $1059.08 \pm 0.16$ , and  $14047.2 \pm 3.0$  for H, D, and  $He^+$ , respectively. These values incorporate more up-to-date estimates for the nuclear finite size effect in D and  $He^+$  than those previously reported.

7427 NOTE ON THE STARK EFFECT FOR LARGE QUANTUM NUMBERS. M.K. Krogdahl.

Astrophys. J. (USA), Vol. 132, No. 3, 906 (Nov., 1960).  
Convergence of existing series expansions for (a) the change in energy of a hydrogen atom due to the presence of an electric field and (b) the change in energy of a proton-hydrogen-atom system due to the van der Waals force is examined for large values of the principal quantum number  $n$ . It is concluded that for convergence the change in energy must be less than  $n^{-3}$ , or that the density of charged particles must be less than  $n^{-15/2}$ . P.M. Parr

7428 DERIVATION OF INTERELECTRONIC SCREENING PARAMETERS FROM STATISTICAL CONSIDERATIONS. R.P. Bauman and J.P. Considine.

J. chem. Phys. (USA), Vol. 34, No. 4, 1388-91 (April, 1961).  
A model for helium and two-electron ions is found in which assumptions similar to that of the Bohr model for the hydrogen atom lead to ionization energies and atomic radii in agreement with observed values and values calculated by the Hartree-Fock method, respectively. An effective screening potential is found by quasi-classical statistical arguments. The angular momentum of each

electron is fixed at one unit and the two electrons constrained to move on the same sphere. The interelectronic distance is assumed to follow an exponential distribution expressed in terms of the Coulombic repulsion. When the distance between electrons is then fixed at its most probable value according to this distribution function, no adjustable parameters remain. The method can be extended to excited states.

**7429 SECOND-ORDER PERTURBATION THEORY OF HELIUM-LIKE IONS.** B.F.Gray and R.Whitehead. *J. chem. Phys. (USA)*, Vol. 34, No. 4, 1243-6 (April, 1961).

A method for calculating the Coulomb interaction between the electrons to the second order of approximation, due to Kessler, is examined and shown to require modification. This removes the discrepancy between the value obtained by Kessler and that obtained by Hylleraas and Midtdal using a variational method, although only very limited accuracy is obtainable.

**7430 A PERTURBATION-VARIATION CALCULATION OF EIGENVALUES.** A.Dalgarno and A.L.Stewart. *Proc. Phys. Soc. (GB)*, Vol. 77, Pt 2, 467-70 (Feb., 1961).

A variational method, based upon perturbation theory, is used to calculate the eigenvalues of the helium sequence. With a trial wave-function containing essentially only one variable parameter, the resulting errors range from 0.3 eV for  $H^-$  to 0.01 eV for  $Ne^{8+}$ .

**7431 MAGNETIC RESONANCE OF ATOMIC LEVELS OF  $He^3$  EXCITED BY ELECTRONIC BOMBARDMENT.** B.Decomps, J.C.Pebay-Peyroula and J.Brossel. *C.R. Acad. Sci. (France)*, Vol. 252, No. 4, 537-9 (Jan. 23, 1961). In French.

A study analogous to that of  $He^4$  (Abstr. 2280 of 1961) gives good agreement with theory for the  $3^3P_2$  and  $3^3P_1$  levels, but suggests a highly anomalous h.f.s. ( $> 600$  Mc/s) in the singlet levels.

J.Hawgood

**7432 SPIN DEPENDENCE OF THE FIRST-ORDER TRANSITION DENSITY MATRIX.** W.A.Bingel. *J. chem. Phys. (USA)*, Vol. 34, No. 3, 1066 (March, 1961). See Abstr. 11483 of 1960.

**7433 ABSOLUTE MEASUREMENT OF THE ATOMIC SCATTERING FACTORS OF IRON, COPPER, AND ALUMINUM.** B.W.Batterman, D.R.Chipman and J.J.DeMarco. *Phys. Rev. (USA)*, Vol. 122, No. 1, 68-74 (April 1, 1961).

The X-ray atomic scattering factors were carefully remeasured to obtain more reliable information on the outer electron charge densities in these elements. The scattering factors were obtained from measurements of the integrated Bragg intensities of powder samples using monochromatic  $Mo K\alpha$  radiation. The intensities were put on an absolute scale by direct measurements of the power in the primary X-ray beam. Extinction, surface roughness, and preferred orientation effects were shown to be negligible in the samples used. The ratios of the measured scattering factors of the three elements agree with those calculated from Hartree-Fock theory to within 1%. This substantiates the findings of Batterman (Abstr. 5258, 1287 of 1959) and, in contrast with the previous results of Weiss and DeMarco (Abstr. 3583, 7651 of 1959) indicates that there is no large discrepancy between the electronic structures of copper and iron. The absolute values of the measured scattering factors, however, lie about 4% below theory in the region of low  $\sin \theta/\lambda$ . It is pointed out that the high theoretical values for iron and copper could result from known differences in electronic structure between a free atom and one in the solid, but that present theory probably cannot account for the discrepancy in the case of aluminium.

**7434 HYPERFINE STRUCTURE AND NUCLEAR MOMENTS OF PROTACTINIUM 233.**

R.Marrus, W.A.Nierenberg and J.Winocur. *Nuclear Phys. (Internat.)*, Vol. 23, No. 1, 90-106 (Feb., 1961).

By means of the atomic-beam magnetic resonance method using radioactive detection, the hyperfine structure of  $_{91}Pa^{233}$  ( $T_{1/2} = 27.4$  days) was investigated. Three low-lying states are found to be present in the beam, characterized by electronic angular momenta  $J = \frac{1}{2}$ ,  $\frac{3}{2}$  and  $\frac{5}{2}$ , and g values  $g_J = -0.8141(4)$ ,  $-0.8062(15)$  and  $-0.7923(15)$  respectively. From these results it is inferred that the ground-state configuration of protactinium is almost certainly  $5f^2(6d)^1(7s)^2$ . The nuclear spin is measured and found to be  $I = \frac{3}{2}$  and the magnetic dipole and electric quadrupole hyperfine structure coupling constants are measured to be  $A = \pm 595(30)$  Mc/s and  $B = \mp 2400(300)$  Mc/s respectively. From a direct measurement, the

nuclear moment is found to be  $\mu_I = +3.4(0.8)$  n.m. From the hyperfine-structure constants and detailed calculations involving the electronic wave-functions, the quadrupole moment is inferred to be  $Q = -3.0$  barns.

**SPECTRA INDUCED BY 200 keV PROTON IMPACT**  
**7435 ON HELIUM.** R.H.Hughes, R.C.Waring and C.Y.Fan. *Phys. Rev. (USA)*, Vol. 122, No. 2, 525-8 (April 15, 1961).

The spectra were observed in the region 3500 to 6000 Å.  $^1S$  states appear to be strongly excited. Absolute cross-sections for the direct excitation of the  $4^1S$  and  $5^1S$  states of neutral helium were determined as well as the simultaneous ionization and excitation cross-section for helium into the  $n = 4$  state of  $He^+$ . Of the more intense lines, only the  $2^1P-n^1S$  lines and the  $He II \lambda 4686$  line behaved linearly with pressure within experimental error. Triplet spectra were observed in which the dominant feature was the  $2^3P-n^3D$  lines. The populations of the  $4^3D$  and  $4^1D$  states, in particular, were analysed as a function of a direct mechanism and collision of the second kind which seem to fit the data fairly well. A very weak Doppler-shifted  $H\beta$  line was detected. If this is interpreted to be produced by charge exchange, then the cross-section for electron capture into the  $n = 4$  state of hydrogen is estimated to be of the order of  $8 \times 10^{-21}$  cm<sup>2</sup>.

**FINE AND HYPERFINE STRUCTURE OF Am I.**  
**7436 K.Krebs and R.Winkler.**

*Z. Phys. (Germany)*, Vol. 162, No. 3, 235-44 (1961). In German. It was previously described (Abstr. 17706 of 1960) how h.f.s. splitting constants can easily be obtained from experimental data by means of a graphical representation. Here it is shown that this method is also capable of conveniently and unambiguously determining the J-values of terms from h.f.s. data. By application of this method to known h.f.s. measurements of the  $Am^{241}$  the undetermined J-value of one Am I term could be obtained. In four other cases J-values were found which differ from the values known so far. The consequences of these redeterminations on the term analysis of Am are discussed.

**MEASUREMENT OF THE HYPERFINE SPLITTING OF THE  $^4F_{5/2}$  GROUND STATE IN THE  $Co^{59}$  I SPECTRUM, AND DETERMINATION OF THE NUCLEAR QUADRUPOLE MOMENT OF  $Co^{59}$ .** D.von Ehrenstein.

*Ann. Phys. (Germany)*, Vol. 7, No. 5-6, 342-52 (1961). In German. Five of the seven splittings were measured with a magnetic atomic-beam resonance apparatus, of which some details are given, particularly of an electron-impact furnace source. Energy differences for the  $F = 8 \rightarrow 7$ ,  $7 \rightarrow 6$ ,  $6 \rightarrow 5$ ,  $5 \rightarrow 4$  and  $4 \rightarrow 3$  transitions, extrapolated to zero magnetic field, are given to one part in 18 000 or better. With existing theory, the magnetic dipole- and nuclear quadrupole exchange constants (A- and B-factors) are computed for the ground state as  $450.284 \pm 0.01$  Mc/s and  $139.63 \pm 0.5$  Mc/s respectively. From these, in conjunction with calculations of the eigenfunction of the ground state, the nuclear quadrupole moment of  $Co^{59}$  is obtained as  $(0.404 \pm 0.04) \times 10^{-24}$  cm<sup>2</sup>. This value, which is some five times as accurate as earlier results, takes into account mixing of electronic states, but not the Sternheimer correction.

J.Sheridan

**HYPERFINE SPLITTING OF RUBIDIUM-87.**

**7438 L.Essen, E.G.Hope and D.Sutcliffe.** *Nature (GB)*, Vol. 189, 298 (Jan. 28, 1961).

The value of the hyperfine structure splitting was measured in a gas cell and in an atomic-beam experiment. Unlike the results for caesium, the two values agree within the experimental error of the gas-cell experiment. The transition frequency for the atomic beam method is  $6\ 834\ 682\ 614.0 \pm 1$  c/s.

G.H.C.Freeman

**THE SOFT X-RAY EMISSION SPECTRA OF SODIUM, BERYLLIUM, BORON, SILICON, AND LITHIUM.**

**7439 R.S.Crisp and S.E.Williams.** *Phil. Mag. (GB)*, Vol. 6, 365-9 (March, 1961).

Emission band forms of several elements obtained with a photon-counting spectrometer are compared with previously published spectra. The sodium  $L_{23}(E)$  versus  $\lambda$  curve departs from the free electron parabola at energies less than about 1 eV from the Fermi limit in accord with the theoretical form. The sodium extrapolated band width is  $2.6 \pm 0.3$  eV. In beryllium K there is no contribution of p states from the bottom of the overlapping second zone. Zone overlap is estimated at 1-2 eV. The extrapolated band width for boron K is estimated at  $14.1 \pm 0.8$  eV. The  $L_{23}$  band of silicon differs from those previously published but is apparently not affected by

the temperature or the purity of the silicon. The extrapolated width is  $13.4 \pm 0.8$  eV. A strong line at 253 Å and a blue fluorescence which accompanies the lithium K spectrum are shown to be connected with the reaction with lithium of hydrocarbon molecules not condensed by the cold trap.

**7440 POPULATION INVERSION AND CONTINUOUS OPTICAL MASER OSCILLATION IN A GAS DISCHARGE CONTAINING A He-Ne MIXTURE.**

A.Javan, W.R.Bennett, Jr and D.R.Herriott.  
Phys. Rev. Letters (USA), Vol. 6, No. 3, 106-10 (Feb. 1, 1961).

Summarizes experimentally observed physical properties of a He-Ne mixture, which facilitated maser oscillations at five wavelengths in the near infrared. Population inversions in Ne were achieved by excitation transfer from the metastable He ( $2^3S$ ) to the  $2S$  levels in Ne. The maser oscillations occurred in a narrow beam, of diameter 0.45 in. and angular spread less than 1 min of arc. The linewidth was between 10 and 80 kc/s and the maximum power obtained was 15 mW at 11.530 Å.

K.A.Thomas

**7441 A STUDY OF OPTICAL PUMPING IN TERMS OF THE DENSITY MATRIX.**

J.P.Barrat and C.Cohen-Tannoudji.  
C.R. Acad. Sci. (France), Vol. 252, No. 1, 93-5 (Jan. 4, 1961).  
In French.

A summary of a theoretical treatment of effects of pumping, with a polarized resonance line, on coherence in the ground state of an assembly of atoms possessing a Zeeman structure. Calculation is made for the transition  $6^1S_0 \rightarrow 6^3P_1$  of the odd isotopes of mercury, but can be immediately generalized for other electric dipole transitions. Equations are derived involving the natural width and the self-energy, and describing the processes of excitation and relaxation, and simplification under appropriate conditions is indicated.

J.Sheridan

**7442 BROADENING AND DISPLACEMENT OF MAGNETIC RESONANCE LINES CAUSED BY OPTICAL PUMPING.**

J.P.Barrat and C.Cohen-Tannoudji.  
C.R. Acad. Sci. (France), Vol. 252, No. 2, 255-6 (Jan. 9, 1961).  
In French.

Earlier theoretical results (see preceding abstract) are shown to describe the longitudinal relaxation caused by optical pumping, which displaces state-populations from their values at thermal equilibrium. Level differences due to differences in self-energies in the presence of the exciting radiation are discussed. Optical pumping can thus lead to broadening and displacement of magnetic resonance lines.

J.Sheridan

**7443 OBSERVATION OF A DISPLACEMENT OF A MAGNETIC RESONANCE LINE CAUSED BY OPTICAL EXCITATION.**

C.Cohen-Tannoudji.  
C.R. Acad. Sci. (France), Vol. 252, No. 3, 394-6 (Jan. 16, 1961).  
In French.

A predicted displacement of a nuclear magnetic resonance line (see preceding abstracts) was observed for the resonance of  $Hg^{199}$  using the arrangement of Cagnac (Abstr. 13483 of 1959) in which the resonance was obtained at 5 kc/s with a primary polarized orientating beam. A second beam, with filters, supplied circularly polarized light of the  $Hg^{201}$  spectrum. Shifts in resonance frequency of 0.4 c/s at constant field were observed, their direction depending on the direction of polarization of the second beam. Intensity changes also depended on the relative directions of polarization of the first and second beams. The detailed results agree with predictions of the theory.

J.Sheridan

**7444 CALCULATION OF THE ELASTIC SCATTERING OF A SLOW ELECTRON BY A NEUTRAL SODIUM ATOM IN THE GROUND STATE.** A.Salmona.

C.R. Acad. Sci. (France), Vol. 252, No. 7, 997-8 (Feb. 13, 1961). In French.

A complete calculation including polarization and exchange terms agrees well with experiment for the overall cross-section, though apparently through some cancellation of errors.

J.Hawgood

**7445 THE EFFECT OF ELECTRON SHELLS ON THE ASYMMETRY EFFECT OF SCATTERED ATOMS.**

T.Tietz.  
Ann. Phys. (Germany), Vol. 7, No. 5-6, 258-62 (1961). In German.

Relations derived for the calculation of the scattering of fast electrons in a Thomas-Fermi force field are shown to be applicable also for the investigation of the influence of electron shells on the asymmetry effect of scattered atoms.

W.J.Orville-Thomas

**PROTON-HYDROGEN SCATTERING SYSTEM.**

7446 M.H.Mittleman.

Phys. Rev. (USA), Vol. 122, No. 2, 499-506 (April 15, 1961).

The impact parameter treatment of the scattering of protons by hydrogen is derived and is shown to be valid for energies greater than a few electron volts. A novel treatment of the resultant equations is given which significantly modifies previous results for inelastic scattering and charge-exchange scattering.

**MORSE POTENTIAL PARAMETERS FOR O-O, N-N AND N-O INTERACTIONS.**

7447

D.D.Konowalow and J.O.Hirschfelder.  
Phys. of Fluids (USA), Vol. 4, No. 5, 637-42 (May, 1961).

More potential parameters are determined for the atom-atom interactions corresponding to the following states having potential minima: the  $X^3\Sigma_g^-, ^1\Delta_g, ^1\Sigma_g^+, ^3\Delta_u, A^3\Sigma_u^+, ^1\Sigma_u^-,$  and  $B^3\Sigma_u^-$  states of O-O (or molecular oxygen); the  $X^1\Sigma_g^+, A^3\Sigma_u^+, B^3\Pi_g,$  a  $^1\Pi_g,$  a  $C^3\Pi_u$  states of N-N (or molecular nitrogen); and the  $X^2\Pi_{1/2}, X^2\Pi_{3/2}, B^2\Pi, C^2\Pi, D^2\Sigma^+, B^1\Delta, E^2\Sigma^+,$  and  $A^2\Sigma^+$  states of N-O (or nitric oxide). For the nitric oxide excited A, D, and  $E^2\Sigma^+$  states, a unique assignment of dissociation products and unique energies of dissociation were obtained by supposing that these three states had the same shape for their potential energy curves. Previously Barrow and Miescher had made this assumption only for the A and  $D^2\Sigma^+$  states and they obtained two possible interpretations. The present analysis suggests the possibility of an unobserved  $^2\Sigma^+$  excited state of NO having a potential minimum  $2454\text{ cm}^{-1}$  above the minimum for the  $D^2\Sigma^+$  state. This new state should dissociate into a ground state nitrogen atom and a  $(2s)^2(2p)^3(3p)^3P$  oxygen atom.

ELECTRON TRANSITIONS IN MULTIPLE COLLISIONS. See Abstr. 7027

IONIZATION PRODUCED BY ATOMIC COLLISIONS AT keV ENERGIES. See Abstr. 7024

## Isotopes

**7446 THE MAGNETO-IONIC EXPANDER ISOTOPE SEPARATOR.** J.Slepian.

J.Franklin Inst. (USA), Vol. 263, No. 2, 129-40 (Feb., 1957).

**7449 THE SINGLE-STAGE FRACTIONATION FACTOR FOR THE SYSTEM OXYGEN VERSUS COBALT DI(SALICYLAL)-ETHYLENEDIAMINE-OXYGEN.**

L.L.Brown and J.S.Drury.  
J. chem. Phys. (USA), Vol. 33, No. 6, 1889-90 (Dec., 1960).

The observed enrichment factor was  $1.0132 \pm 0.002$ ; the heavy oxygen isotope enriches in the gas phase. The experimental method is described.

W.G.

## Mesic Atoms

**AUGER RATE IN  $\mu$ -MESIC ATOMS.**

7450 A.Pevsner, R.Strand, L.Madansky and T.Toohig.  
Nuovo Cimento (Italy), Vol. 19, No. 3, 409-14 (Feb. 1, 1961).

A study was made of the K Auger transitions in the light elements of nuclear emulsions. Of 3382 stopping  $\mu^-$ -mesons, 101 were observed to decay. 5 of these had associated short-range electrons whose energies were consistent with the K transitions of CNO. 2 of these 5 are attributed to the K Auger transitions of CNO, while the remaining 3 are attributed to the K Auger transitions in AgBr. These results are to be compared with the calculations of Burbidge and de Borde which predict 1.3 K Auger electrons from CNO for this experiment. These experimental results are inconsistent with the assumption that the missing K radiative transitions in the experiment of Stearns and Stearns are due to competing Auger processes, since this would require 294 observed K electrons as compared to the 2 actually observed. The experimental results quoted here are in agreement with an earlier experiment of Fry.

## MOLECULES

- 7451 **TABLE OF TWO-CENTRE INTEGRALS. II.**  
J. Baudet, F. Cabaret, J. Tillieu and J. Guy.  
J. Phys. Radium (France), Vol. 21, No. 2, 105-11 (Feb., 1960).  
In French.  
Integrals occurring in the study of molecular properties (especially magnetic susceptibilities) are tabulated in a condensed form, allowing fast numerical calculations. This table is the continuation of Abstr. 3351 of 1957.
- 7452 **POTENTIAL ENERGY CONSTANTS, ROTATIONAL DISTORTION CONSTANTS, AND THERMODYNAMIC PROPERTIES OF STIBINE.** S. Sundaram.  
Canad. J. Phys., Vol. 39, No. 2, 370-3 (Feb., 1961).  
Reports results of investigations on  $\text{SbH}_3$  similar to previous work on  $\text{NH}_3$ ,  $\text{PH}_3$ , etc. (See Abstr. 4187 of 1960). J. Hawgood
- 7453 **FORCE CONSTANTS OF CHLORO- AND BROMO-METHANES.** T. Shimanouchi and I. Suzuki.  
J. molecular Spectrosc. (USA), Vol. 6, No. 3, 277-300 (March, 1961).  
The calculation of the normal vibrations has been made for  $\text{CH}_3\text{Cl}$ ,  $\text{CD}_3\text{Cl}$ ,  $\text{CH}_2\text{Cl}_2$ ,  $\text{CD}_2\text{Cl}_2$ ,  $\text{CHCl}_3$ ,  $\text{CDCl}_3$ ,  $\text{CH}_2\text{Br}$ ,  $\text{CD}_2\text{Br}$ ,  $\text{CH}_2\text{Br}_2$ ,  $\text{CD}_2\text{Br}_2$ ,  $\text{CHBr}_3$ , and  $\text{CDBr}_3$  molecules. The stretching, bending and repulsive force constants and internal tensions of these molecules have been obtained from the vibrational frequencies by the method of least squares. The transferability and the tendency of change of these constants have been discussed.
- 7454 **THE FRANCK-CONDON FACTOR ( $q_{v',v''}$ ) ARRAY TO HIGH VIBRATIONAL QUANTUM NUMBERS FOR THE  $\text{O}_2(\text{B}^3\Sigma_u^- - \text{X}^3\Sigma_g^-)$  SCHUMANN-RUNGE BAND SYSTEM.** R. W. Nicholls.  
Canad. J. Phys., Vol. 38, No. 12, 1705-10 (Dec., 1960).  
A Franck-Condon factor  $q_{v',v''}(|\delta\psi_{v'}\psi_{v''}|^2)$  array was computed for a Morse model by direct numerical integration over the range of quantum numbers  $0 < v' < 21$ ;  $0 < v'' < 21$ . R. W. Nicholls
- 7455 **A NOTE ON THE HIGH-SPEED COMPUTATION OF ROTATIONAL CONSTANTS AND INTERATOMIC DISTANCES FROM STRUCTURAL PARAMETERS.**  
R. H. Schwendeman.  
J. molecular Spectrosc. (USA), Vol. 6, No. 3, 301-4 (March, 1961).  
A programme is described for the high-speed digital computation of rotational constants and interatomic distances directly from structural parameters in the form of bond lengths and bond angles. The programme accepts as input the spherical polar coordinates of each atom, computes their Cartesian coordinates, and subsequently calculates the rotational constants and interatomic distances and angles. Sufficient flexibility in the choice of origin and orientation of axis system is allowed to cope with the great variety of structures which exist.
- 7456 **COMPUTER ANALYSIS OF INFRARED AND RAMAN BANDS OF SYMMETRIC TOP MOLECULES.**  
S. Brodersen and E. H. Richardson.  
J. molecular Spectrosc. (USA), Vol. 6, No. 2, 265-71 (Feb., 1961).  
A programme is presented for the direct calculation of the rotational constants from the frequencies and quantum numbers of the assigned lines in an infrared or Raman band of a symmetric top molecule. The calculation is based on the least-squares principle using estimated experimental errors on the frequencies to obtain the relative weights of the observations. The output contains all the constants which may be determined from the given collection of transitions, their probable errors, and all the calculated frequencies.
- 7457 **PERTURBATION FORMULAS FOR THE ENERGY LEVELS OF THE SLIGHTLY ASYMMETRIC TOP.**  
J. L. Davis and J. E. Beam.  
J. molecular Spectrosc. (USA), Vol. 6, No. 3, 312-18 (March, 1961).  
Using the adiabatic theorem, a new perturbation method is developed for obtaining the energy levels of the slightly asymmetric top. Then, by expanding the energy levels in terms of Wang's symmetry parameter  $b = (C - B)/(2A - B - C)$ , general formulas are obtained for the coefficients of  $b^n$  through  $n = 7$  for all values of  $J$  and  $K$ .

7458 **THIRD-ORDER CORRECTIONS TO THE VIBRATION-ROTATION ENERGY OF POLYATOMIC MOLECULES.**

- S. Maes.  
Cahiers de Phys. (France), Vol. 14, 125-208 (April-May, 1960).  
In French.  
Careful discussion and theoretical evaluation of some of the third-order terms in the Goldsmith-Amat-Nielsen approach to vibration-rotation energies (e.g. Abstr. 369-70 of 1958). General expressions are given for the matrix elements of the third-order transformed Hamiltonian  $h_3$  and their coefficients, and descriptions are given of the outlines of calculations of these quantities for some particular types of symmetry. The effects of third-order resonances are studied in some detail, particularly the Taylor-Benedict-Strong correction to the Fermi resonance term for a linear triatomic molecule (Abstr. 1531 of 1953), which is shown not to be  $l$ -dependent but to which a new  $J$ -dependent term is added. The proposed expressions agree better with experiment than do those of some previous authors. J. Hawgood

7459 **VIBRATIONAL MEAN-SQUARE AMPLITUDE MATRICES. VIII. MEAN-SQUARE PARALLEL AND PERPENDICULAR AMPLITUDES OF TETRAHEDRAL  $\text{XY}_4$  MOLECULES.** S. J. Cyvin.

- J. molecular Spectrosc. (USA), Vol. 6, No. 3, 333-7 (March, 1961).  
For Pt VII see Abstr. 1772 of 1960. The theory of computing mean-square parallel and perpendicular amplitudes from spectroscopic data, developed by Morino and Hirota, is summarized. A slightly modified method is proposed, connecting these quantities to the concept of mean-square amplitude matrices. As a particular case, the tetrahedral  $\text{XY}_4$  molecular model is considered, and all the nonvanishing generalized mean-square amplitudes for the bonded and nonbonded distance types are given. The quantities are expressed as linear combinations of the symmetrized mean-square amplitude matrices.

7460 **VIBRATIONAL MEAN-SQUARE AMPLITUDE MATRICES. IX. GERMANIUM TETRACHLORIDE.**

- S. J. Cyvin.  
J. molecular Spectrosc. (USA), Vol. 6, No. 3, 338-42 (March, 1961).  
The theory of mean-square amplitude matrices ( $\Sigma$ ) is applied to the germanium tetrachloride molecule. The following quantities are computed from the spectroscopic vibrational frequencies, along with the electron-diffraction value for the Cl-Cl mean-square amplitude of vibration: (a)  $\Sigma$  matrix elements at  $298^\circ\text{K}$ , (b) additional mean-square amplitude quantities at  $298^\circ\text{K}$ , including the Ge-Cl mean-square amplitude of vibration. This value is quite compatible with the reported result from electron-diffraction. (c) L-matrix elements, (d) force constants, (e) perpendicular mean-square amplitudes at  $298^\circ\text{K}$  for the Ge-Cl and Cl-Cl atom pairs.

7461 **THE STRUCTURE OF THE VIBRATIONAL-ROTATIONAL BANDS OF AN ASYMMETRIC ROTOR.**

- H. C. Allen, Jr.  
Phil. Trans A (GB), Vol. 253, 335-57 (April 27, 1961).  
The structure of A-, B- and C-type bands is related to those of the two limiting symmetric rotors. The effect of the degree of asymmetry and the changes in the effective inertial constants between the two vibrational states on the band structure is shown. The type of information which can be obtained from the analysis is pointed out.

7462 **MICROWAVE SPECTRUM OF CIS 1-CHLORO-2-FLUOROETHYLENE.** J. A. Howe.

- J. chem. Phys. (USA), Vol. 34, No. 4, 1247-9 (April, 1961).  
The microwave spectrum of cis 1-chloro-2-fluoroethylene,  $\text{CHCl}=\text{CHF}$ , was observed in the 15-25 kMc/s region for both chlorine species. Rotational constants for  $\text{CHCl}^3\text{CHF}$  are  $a = 16405.9$ ,  $b = 3756.05$ , and  $c = 3052.67$  Mc/s. Agreement of these and other data with values predicted from an assumed structure strongly suggests that the structure can be well represented as a composite of the known vinyl chloride and vinyl fluoride structures. Second-order quadrupole coupling theory is used to afford a direct measurement of  $\chi_{ab}$ ; the nonzero elements of the tensor  $\chi$  for the  $\text{Cl}^{35}$  species have the values  $\chi_{aa} = -22.46$ ,  $\chi_{bb} = -10.88$ , and  $\chi_{ab} = \pm 56.7$  Mc/s. These values show a 4% deviation of the C-Cl bond from cylindrical symmetry.

7463 **MICROWAVE SPECTRUM OF ETHYL IODIDE. I.** T. Kasuya and T. Oka.

- J. Phys. Soc. Japan, Vol. 15, No. 2, 296-303 (Feb., 1960).  
The rotational constants obtained are:  $A = 29106.2 \pm 0.5$  Mc/s,  $B = 2979.2 \pm 0.1$  Mc/s and  $C = 2797.1 \pm 0.1$  Mc/s, which lead to the

structure as  $d_{\text{CI}} = 2.139 \pm 0.005$  Å and angle  $\text{CCI} = 112^\circ 10' \pm 20'$  with the assumption of  $d_{\text{CC}} = 1.54$  Å. The calculation of the second order quadrupole effects for a slightly asymmetric molecule with a plane of symmetry gave the asymmetry parameter  $\eta = (q_{\text{bb}} - q_{\text{cc}})/q_{\text{aa}}$  of  $0.205 \pm 0.005$  and  $\xi = q_{\text{ab}}/q_{\text{aa}}$  of  $-0.57 \pm 0.05$  as well as the coupling constant  $eqQ$  of  $-1771 \pm 10$  Mc/s along the C-I bond. The components of the electric dipole moment were determined to be  $\mu_a = 1.75 \pm 0.05$  D and  $\mu_b = 0.25 \pm 0.1$  D. Centrifugal constants were obtained as  $D_K = 0.36 \pm 0.05$  Mc/s,  $D_{JK} = -0.151 \pm 0.005$  Mc/s and  $D_J < 0.05$  Mc/s.

7464 MICROWAVE ZEEMAN EFFECT OF FORMALDEHYDE.  
K.Kondo, H.Hirakawa, A.Miyahara, T.Oka and K.Shimoda.

J. Phys. Soc. Japan, Vol. 15, No. 2, 303-6 (Feb., 1960).

Zeeman effects in the absorption spectra of formaldehyde  $\text{H}_2\text{CO}$ , HDCO, and  $\text{D}_2\text{CO}$  were studied in the microwave region with magnetic fields of  $\sim 1500$  Oe. The effective g-values in several rotational states and the elements of the g-tensor,  $g_{\text{aa}}$ ,  $g_{\text{bb}}$ , and  $g_{\text{cc}}$  of these molecules were determined. Dependences of the effective g-values on the rotational quantum numbers J,  $\tau$  were consistent among these isotopically substituted molecules. The components of the g-tensors of these molecules were found to be  $g_{\text{aa}} = 2.86 \pm 0.04$  for  $\text{H}_2\text{CO}$ ,  $2.00 \pm 0.05$  for HDCO, and  $1.46 \pm 0.05$  for  $\text{D}_2\text{CO}$ . They are extraordinarily large compared to those of other molecules already known. A brief qualitative interpretation is given.

7465 STARK-ZEEMAN EFFECTS ON ASYMMETRIC TOP MOLECULES. FORMALDEHYDE  $\text{H}_2\text{CO}$ .

K.Kondo and T.Oka.

J. Phys. Soc. Japan, Vol. 15, No. 2, 307-14 (Feb., 1960).

The combined Stark-Zeeman effects for asymmetric top molecules with no accidental degeneracies were studied by perturbation treatments. The theory was applied successfully to the analysis of the experimental results of the Stark-Zeeman effect on the microwave spectrum of formaldehyde  $\text{H}_2\text{CO}$ . By the influence of the electric field perpendicular to the magnetic field, split components of the transition  $2_{11} \rightarrow 2_{12}$  which, in the magnetic quantum number M, correspond to  $\Delta M = \pm 3$  were observed. These components allowed a precise determination of the molecular g-factor for this transition.

7466 POTENTIAL BARRIER OF PHENOL FROM ITS MICROWAVE SPECTRUM. T.Kojima.

J. Phys. Soc. Japan, Vol. 15, No. 2, 284-7 (Feb., 1960).

The microwave spectrum of phenol,  $\text{C}_6\text{H}_5\text{O}^{16}\text{H}$ , was measured in the frequency range from 15 to 30 Gc/s. Most of the spectral lines were found to be doublet, which is explained as the effect of internal rotation of the OH group in a hindering potential of the form  $V = \frac{1}{2}V_2(1 - \cos 2x)$ . The barrier height,  $V_2$ , was determined to be  $1100 \pm 100$  cm $^{-1}$  from the observed splittings. By the use of a rigid rotor model, the effective rotational constants were calculated to be  $A = 5650.46$  Mc/s,  $B = 2619.20$  Mc/s, and  $C = 1789.84$  Mc/s. From these values, the OH bond in its equilibrium configuration was found to lie on the plane comprising the  $\text{C}_6\text{H}_5$  group.

7467  $\nu_6$  VIBRATION OF ADSORBED ETHYLENE.  
L.H.Little.

J. chem. Phys. (USA), Vol. 34, No. 1, 342-3 (Jan., 1961).

Detailed study of the i.r. spectra of deuterated ethylenes led to the assignment of the  $\nu_6$ -C-H stretching vibration to a band at 3075 cm $^{-1}$ . The spectrum of ethylene adsorbed on porous glass shows bands at 3093 and 2977 cm $^{-1}$  due to the i.r. allowed  $\nu_6$  and  $\nu_{11}$ -C-H stretching vibrations, a band at 3007 cm $^{-1}$  assigned to the  $\nu_1$  totally symmetric C-H stretching mode and a band at 3070 cm $^{-1}$  which it is suggested is due to the  $\nu_6$  vibration appearing in the spectrum of the adsorbed ethylene due to loss of symmetry and perturbation by the surface.

R.C.Seymour

7468 THE TORSIONAL OSCILLATION FREQUENCY OF  $\text{H}_2\text{O}_2$ .  
D.Chin and P.A.Giguère.

J. chem. Phys. (USA), Vol. 34, No. 2, 690-1 (Feb., 1961).

Measurements on  $\text{H}_2\text{O}_2$  vapour, by the method of Abstr. 4529 of 1955 but extending to longer wavelengths (33  $\mu$ ), show that the earlier interpretation of the bands at 16 and 20  $\mu$  as a torsional doublet must be revised; the torsional frequency  $\nu_4$  is now found to be 314 cm $^{-1}$ , the band at 575 cm $^{-1}$  being the first overtone. There being no resolved doubling in these bands, other doublings can no longer be ascribed to the double minimum in the torsional potential.

J.Hawgood

INFRARED SPECTROSCOPY AND MOLECULAR STRUCTURE. H.H.Nielsen.

7469 J. Phys. Radium (France), Vol. 21, No. 1, 24-30 (Jan., 1960). In French.

Even if a molecule has no permanent electric moment, its infrared spectrum contains rotation bands if the vibrations of the molecule induces an electric moment. In the case of axially symmetrical molecules, the induced moment can be parallel to the axis, and give rise to "parallel" bands, or perpendicular to the axis, and give rise to perpendicular bands. If these bands can be resolved, their analysis permits computing the two different moments of inertia, and obtaining a considerable amount of information concerning the size and the shape of the molecule.

7470 INFRARED SPECTRA OF THE LITHIUM HALIDE DIMERS. W.Klemperer and W.G.Norris.

J. chem. Phys. (USA), Vol. 34, No. 3, 1071-2 (March, 1961).

Absorption maxima, tentatively ascribed to the  $\text{B}_{2u}$  and  $\text{B}_{3u}$  im plane bond stretching motions in the gaseous dimers have been observed as follows:

|      |     |     |            |
|------|-----|-----|------------|
| LiF  | 640 | 460 | cm $^{-1}$ |
| LiCl | 460 | 335 |            |
| LiBr | 413 | 295 |            |
| LiI  | 375 | 248 |            |

R.F.Barre

EXCITATION OF  $\text{O}_2$  ATMOSPHERIC BANDS IN THE AURORA  
See Abstr. 6639

7471 INFRARED SPECTRUM OF STANNANE.

L.May and C.R.Dillard.  
J. chem. Phys. (USA), Vol. 34, No. 2, 694-5 (Feb., 1961).

The thermodynamic functions of  $\text{SnH}_4$  are calculated from the infrared spectral results.

G.I.W.Llewellyn

7472 INFRARED SPECTRA AND POTENTIAL CONSTANTS OF SOME MONOHALOACETYLENES.

G.R.Hunt and M.K.Wilson.

J. chem. Phys. (USA), Vol. 34, No. 4, 1301-7 (April, 1961).

The infrared spectra of gaseous  $\text{HC}\equiv\text{CF}$ ,  $\text{HC}\equiv\text{CCl}$ , and  $\text{HC}\equiv\text{CBr}$  and their deuterio-compounds were obtained under prism dispersion between 250 and 3500 cm $^{-1}$ . All five fundamental vibrations were identified for each of the hydrogen compounds and all but the lower bending mode for each of the deuterated compounds. Potential constants and vibrational amplitudes are calculated.

7473 RAMAN SPECTRA OF CHLOROFORM AND METHYL ALCOHOL IN GASEOUS STATE.

P.Simova and B.Skorchev.

C.R. Acad. Bulg. Sci., Vol. 13, No. 4, 395-8 (July-Aug., 1960).

The experimental arrangement is described and the results obtained tabulated and compared with previously recorded data on Raman and infrared spectra of these substances in the gaseous state.

G.I.W.Llewellyn

7474 RAMAN INTENSITIES AND THE STRUCTURE OF SOME OXYANIONS OF GROUP VII.

G.W.Chantry and R.A.Plane.

J. chem. Phys. (USA), Vol. 34, No. 4, 1268-71 (April, 1961).

In order to obtain information concerning bonding and to test a hypothesis concerning the non-existence of  $\text{BrO}_4^-$ , the absolute intensities and depolarization ratios were determined for Raman lines of  $\text{ClO}_3^-$ ,  $\text{BrO}_3^-$ ,  $\text{IO}_3^-$ ,  $\text{IO}_4^-$ , and  $\text{H}_5\text{IO}_6$ . From the data, values of  $\alpha_{\text{LO}}$  are obtained. These show that  $\text{ClO}_3^-$  resembles previously studied ions in containing sufficient  $\pi$  bonding to achieve essential electrical neutrality. Values for the other oxyhalides are consistent with this interpretation; however, an independent criterion based on depolarization ratios (which are apparently greater for  $\text{BrO}_3^-$  and  $\text{IO}_3^-$  than for  $\text{ClO}_3^-$ ) indicates that there is less  $\pi$  bonding in  $\text{BrO}_3^-$  and  $\text{IO}_3^-$  than in  $\text{ClO}_3^-$ . Since neither criterion can be applied rigorously to these examples, it is difficult to decide which explanation is correct or whether the truth lies intermediate between the two extremes.

7475 THE EMISSION SPECTRUM OF BISMUTH MONOCHLORIDE MOLECULE: THE ROTATIONAL STRUCTURE AND THE ELECTRONIC TRANSITION OF THE BAND SYSTEM 6170-4220 Å. B.N.Khanna.

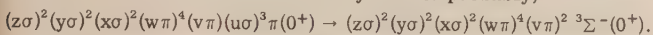
J. molecular Spectrosc. (USA), Vol. 6, No. 3, 319-32 (March, 1961).

The rotational structure of the  $\text{BiCl}$  bands has been obtained for the first time and the rotational lines of the five bands (0,2), (0,3),

(0,4), (1,2) and (1,1) have been analysed. The molecular constants obtained are:

$$\begin{aligned} B_0' &= 0.101_{\text{g}} \text{ cm}^{-1}, & B_2'' &= 0.114_1 \text{ cm}^{-1}, \\ B_1' &= 0.101_{\text{g}} \text{ cm}^{-1}, & B_3'' &= 0.113_{\text{g}} \text{ cm}^{-1}, \\ B_1'' &= 0.114_{\text{g}} \text{ cm}^{-1}, & B_4'' &= 0.112_{\text{g}} \text{ cm}^{-1}, \\ B_e' &= 0.102 \text{ cm}^{-1}, & B_e'' &= 0.115 \text{ cm}^{-1}. \end{aligned}$$

A detailed consideration of the electronic configuration and the probable low-lying electronic states is given. This along with the experimental observation that only P and R branches occur in the rotational structure, shows that the coupling in the molecule is probably of the Hund's Case (c) type and that the electronic transition involved in the emission of the system is probably,



#### 7476 THE ULTRAVIOLET EMISSION SPECTRUM OF NAPHTHALENE VAPOR. D.E.Freeman.

J. molecular Spectrosc. (USA), Vol. 6, No. 3, 305-11 (March, 1961).

This spectrum (as excited by r.f. oscillations of about 20 m wavelength) consists of discrete bands superposed on a continuum. The existence of an origin (at 32017  $\text{cm}^{-1}$ ) and the activity of vibrations of symmetries  $a_g$  and  $b_{3g}$  are consistent with the view that the lowest singlet electronic transition is allowed and long-axis polarized.

#### $n \rightarrow \pi^*$ ELECTRONIC TRANSITION IN PURE ALKALI NITRATE MELTS. See Abstr. 6861

#### 7477 STUDY OF THE EFFECT OF IONIZATION AND OF THE CHEMICAL BOND ON THE ELECTRON DENSITY OF THE CH RADICAL. M.Cornille.

Cahiers de Phys. (France), Vol. 14, 497-511 (Dec., 1960). In French.

Describes calculations comparing the electron densities and populations obtained from the following wave functions: (a) an SCF function for CH, (b) an SCF function for  $\text{CH}^+$ , (c) a function for  $\text{CH}^+$  obtained from (a) by suppressing the  $\pi$  orbital, i.e. by using Koopmans' theorem. Functions (a) and (b) were taken from Abstr. 7449 of 1958. It is found that the Koopmans approximation (c) disagrees with (b) by indicating that the effect of ionization on the electron density is localized round the C atom. The effect of the bonding, found by comparison with free atom densities for C and H, is to increase the density round the H atom and on the far side of the C atom, with only a small increase in the "bond" region.

J.Hawgood

#### 7478 IONIZATION POTENTIALS OF BENZENE, HEXA-DEUTEROBENZENE, AND PYRIDINE FROM THEIR OBSERVED RYDBERG SERIES IN THE REGION 600-2000 Å.

M.F.A.El-Sayed, M.Kasha and Y.Tanaka. J. chem. Phys. (USA), Vol. 34, No. 1, 334-5 (Jan., 1961).

The observation of the Rydberg series led to ionization potentials as follows; benzene 9.24<sub>g</sub>, 11.48<sub>g</sub> and 16.84 eV;  $\text{C}_6\text{D}_6$  9.25, 11.52 and 16.87 eV; pyridine 9.26<sub>g</sub> and 11.56 eV. There is a preliminary discussion of the molecular orbitals involved. A.G.Gaydon

#### 7479 CONTRIBUTIONS TO THE GENERAL THEORY OF LCAO-MO METHOD.

M.I.Bán, F.J.Gilde, and J.I.Horváth. Acta. phys. chem. Szeged (Hungary), Vol. 6, No. 1-4, 8-17 (1960).

The coefficients of the AO's in different MO's belonging to degenerate energy states and the physical quantities dependent on these coefficients, as well, are not unequally determined, but are dependent on diophantic parameters of uncertainty. It is proved that: (1) the diophantic parameters of uncertainty refer to rotations in the eigenspace of MO's belonging to degenerate energy states; (2) in the case of closed shells of MO's the physical quantities are independent of the diophantic parameters of uncertainty; (3) the physical quantities in the case of non-closed electron shells of MO's are only independent of the diophantic parameters of uncertainty if the "number of electrons" is the same on the different MO's corresponding to the same energy.

#### 7480 COMMENT ON THE DIFFERENCE BETWEEN THE BOND ORDERS CALCULATED BY SCF MO AND SIMPLE MO METHOD. M.Randić.

J. chem. Phys. (USA), Vol. 34, No. 2, 693-4 (Feb., 1961). Bond orders obtained by the SCF MO method and the Hückel MO approximations for eleven polycyclic aromatic hydrocarbons are compared. In all cases it is seen that the refinements which occur on the introduction of self-consistency are equivalent to giving extra weight to one of the stable Kekule structures in the conventional valence bond theory. T.E.Peacock

#### PI BONDING IN URANYL ION.

7481 R.I.Belford and G.Belford.

J. chem. Phys. (USA), Vol. 34, No. 4, 1330-4 (April, 1961).

Overlap integrals are calculated for possible primary bonds of uranyl ion. The  $6d \sigma$  and  $\pi$  overlaps are about the same and so great that considerable bonding of  $\sigma d$  and  $\pi d$  types is indicated. The  $5f \sigma$  and  $\pi$  overlap integrals are about the same and quite small, but strong  $\sigma f$  bonding cannot be ruled out.

#### 7482 MOLECULAR ORBITAL THEORY AND HYPERFINE SPLITTING IN ELECTRON SPIN RESONANCE SPECTRA OF SEMIQUINONES. G.Vincow and G.K.Fraenkel.

J. chem. Phys. (USA), Vol. 34, No. 4, 1333-43 (April, 1961).

Molecular orbital calculations of the unpaired electron density in a number of semiquinone ions are made as a function of a range of values of the Coulomb integral  $\alpha_0$  for the oxygen atom and the resonance integral  $\beta_{CO}$  between the oxygen atom and the carbon atom. The unpaired electron densities  $p_i$  were compared with the experimental hyperfine splitting constants  $a_i$  arising from the proton bonded to carbon atom  $i$  by the use of McConnell's relation  $a_i = Qp_i$ . Excellent agreement is obtained for the proper choice of  $\alpha_0$  and  $\beta_{CO}$ . In contrast to most experimental tests of molecular orbital theory, the agreement depends rather critically on the choice of these two parameters. The best values found for the parasemiquinone ions are in the neighbourhood of  $\alpha_0 \cong \alpha_C + 1.2 \beta_{CC}$  and  $\beta_{CO} \cong 1.56 \beta_{CC}$ . The values of  $|Q|$  are close to 22.5 gauss. A different set of parameters is needed for the orthosemiquinones. The molecular orbital calculation also fits the experimental splitting constants of the ring protons in the positions meta and para to the methyl group of the tolusemiquinone ion, but there is a large discrepancy at the position ortho to the methyl group. The results of detailed examination of a number of spectra of semiquinone ions are also reported.

#### 7483 APPROXIMATIONS USED IN THE CALCULATION OF DIAMAGNETIC MOLECULAR SUSCEPTIBILITIES.

J.Guy, J.Baudet and J.Tillieu.

J. Phys. Radium (France), Vol. 21, No. 1, 59-64 (Jan., 1960). In French.

When the electronic eigenfunction (fundamental state) of a molecule is given in the form of a non-antisymmetrized product of orbitals, the calculation of the diamagnetic susceptibility tensor depends on a system of partial differential equations which cannot be solved rigorously in practice. With the aid of some restrictive hypotheses concerning the analytical form of the perturbed orbitals (application of magnetic field) it is shown that it is possible to replace the original perturbation equations by linear second-order differential equations. These last equations are in fact a generalization of the more simple methods previously used. A careful discussion indicates when it will be effectively preferable to solve numerically the new equations obtained.

#### 7484 THE CALCULATION OF DIAMAGNETIC SUSCEPTIBILITIES. J.Guy.

Cahiers de Phys. (France), Vol. 14, 418-24 (Oct., 1960). In French.

In this paper are described the various stages in relatively simple theoretical calculations, employing variational techniques, which yield values for susceptibilities in excellent accord with those observed. W.J.Orville-Thomas

#### VARIATION OF MAGNETIC SCREENING CONSTANTS

#### 7485 WITH DISTANCE FOR SPHERICALLY SYMMETRIC ORBITALS. J.Guy, F.Cabaret and J.R.Didry.

C.R.Acad. Sci. (France), Vol. 252, No. 9, 1296-8 (Feb. 27, 1961). In French.

Describes calculations of single-orbital screening constants for spherically symmetric orbitals, using the methods of Abstr. 379 of 1958. It is shown that the screening constant for a hydrogen-like orbital does not vary as  $1/R^3$  for large  $R$ , as often assumed ( $R$  being the distance from the nucleus considered to the centre of the orbital).

J.Hawgood

#### 7486 CARBON-13 HYPERFINE SPLITTINGS IN SEMIQUINONES. D.C.Reitz, F.Dravnies and J.E.Wertz.

J. chem. Phys. (USA), Vol. 33, No. 6, 1880-1 (Dec., 1960).

The electron spin resonances of semiquinone and 2,5-dihydroxysemiquinone show, besides the hyperfine splittings due to the ring protons alone, weak hyperfine lines attributable to the presence of  $\text{C}^{13}$  in natural abundance. An empirical relation is used to estimate from the observed  $\text{C}^{13}$  splittings the  $\pi$ -electron spin densities at the carbon and oxygen atoms. E.F.W.Seymour

**7487 PROTON HYPERFINE SPLITTINGS AND SPIN DENSITIES OF PENTAPHENYLCYCLOPENTADIENYL.**

D.C.Reitz.

J. chem. Phys. (USA), Vol. 34, No. 2, 701-2 (Feb., 1961).

The  $\pi$ -electron spin densities on the carbon atoms of this radical are calculated using simple Hückel MO theory and the Pauling-Wheland valence bond theory. The pattern of spin densities obtained is close to that predicted for odd alternant systems (Abstr. 4233 of 1960). The values obtained compare well with those obtained from proton hyperfine splittings. T.E.Peacock

**EFFECT OF MAGNETIC NONEQUIVALENCE IN  $A_2B_2$**

**7488 N.M.R. SPECTRA.** D.M.Grant and H.S.Gutowsky.

J. chem. Phys. (USA), Vol. 34, No. 2, 699-700 (Feb., 1961).

The proton magnetic resonance spectra of several compounds were interpreted on the basis of accidentally equal cis and trans spin-spin couplings between the A and B nuclei. Computations are reported showing that the spectra would be hardly altered even if the couplings were significantly unequal. E.F.W.Seymour

**CORRELATION OF PROTON MAGNETIC RESONANCE SHIFTS WITH GROUP DIPOLE MOMENTS IN SUBSTITUTED ETHYLENES.**

G.S.Reddy, C.E.Boozer and J.H.Goldstein.

J. chem. Phys. (USA), Vol. 34, No. 2, 700-1 (Feb., 1961).

Linear relations are found between the chemical shifts of both the cis and trans  $\beta$ -protons in a series of substituted ethylenes  $H_2C=CHX$ , and the group dipole moments of the substituent X, where  $X = H, CH_3, Cl, OCH_3, CN$ , and  $C_6H_5$ . E.F.W.Seymour

**7490 THEORETICAL NUCLEAR MAGNETIC RESONANCE CURVES FOR COMPLEX FORMATION AND DISSOCIATION.** G.Mavel.

J. Phys. Radium (France), Vol. 21, No. 1, 37-46 (Jan., 1960). In French.

Using the Gutowsky-Saika chemical exchange laws, theoretical nuclear magnetic resonance curves are established for complex formation and dissociation phenomena; it is possible to account for separate elementary processes using their independent equilibria (in first approximation) in a binary mixture.

**7491 INDIRECT NUCLEAR SPIN-SPIN COUPLINGS IN SATURATED HYDROCARBON MOLECULES.** E.Hiroike.

J. Phys. Soc. Japan, Vol. 15, No. 2, 270-84 (Feb., 1960).

A general formula for the coupling constant  $J_{HH'}$  between two hydrogen nuclei is derived by means of the valence bond method. Almost all the structures, which are obtained by Rumer's theorem, are taken into account. The calculated value of  $J_{HH'}$  in a methane molecule is  $12.1 \text{ sec}^{-1}$ , which is in good agreement with experiment. It is shown that an approximate formula for  $J_{HH'}$ , which is derived from the general one, is convenient to discuss its qualitative behaviour.

**NUCLEAR INTERACTIONS IN DEUTERIUM FLUORIDE.**

**7492 H.M.Nelson, J.A.Leavitt, M.R.Baker and N.F.Ramsey.**

Phys. Rev. (USA), Vol. 122, No. 3, 856-9 (May 1, 1961).

The deuteron and fluorine magnetic resonance spectra in the molecule DF were studied using the molecular beam method, and the observed resonance patterns compared with those calculated on a computer. The parameters of the calculation were adjusted until the theoretical and the experimental curves matched. In this manner the spin-rotational interaction constant of fluorine in DF was assigned the value  $|c_F| = 160 \pm 1 \text{ kc/s}$  and the quadrupole coupling constant of the deuteron in DF was assigned the value  $|d_d| = 34 \pm 4 \text{ kc/s}$ , which corresponds to  $|eqQ/h| = 340 \pm 40 \text{ kc/s}$ .

**7493 NUCLEAR SPIN-SPIN INTERACTION ENERGY IN THE HYDROGEN MOLECULE.**

J.P.Auffray and J.W.Cooley.

Phys. Rev. (USA), Vol. 122, No. 4, 1203 (May 15, 1961).

An accurate theoretical estimate of the interaction energy of the two proton magnetic moments in the  $v = 0, J = 1$  vibrational-rotational level of the electronic ground state of  $H_2$  is obtained. Agreement with the experimental value for the nuclear spin-spin interaction energy is found to be within 1 part in  $10^3$ . This is of the order of magnitude of the experimental error.

**7494 PHOTOIONIZATION OF ALKANES. DISSOCIATION OF EXCITED MOLECULAR IONS.**

B.Steiner, C.F.Giese and M.G.Inghram.

J. chem. Phys. (USA), Vol. 34, No. 1, 189-220 (Jan., 1961).

Describes a thorough experimental study (by the method of Abstr. 9742 of 1957) of the photoionization and subsequent disso-

ciation of all saturated paraffins from  $C_2$  to  $C_8$ , and of n-heptane and n-octane, for photon energies up to 11.9 eV. It was found that the adiabatic ionization potentials could not be determined, as this transition is not accessible to ordinary impact experiments, and that the absolute values of bond dissociation energies could not be found, though relative values are tabulated tentatively. Careful comparison with the predictions of the statistical theory of dissociation kinetics indicates that this theory fails to explain the observations. J.Hawgood

**COLLISION-INDUCED DISSOCIATION OF  $HD^+$ .**

**7495 A.P.Irsa and L.Friedman.**

J. chem. Phys. (USA), Vol. 34, No. 1, 330-1 (Jan., 1961).

Cross-section determinations for the dissociation of  $HD^+$  are made from a mass spectrometric study and the results compared with the conflicting data of Sweetman (Abstr. 19610 of 1960) and Fedorenko et al. (Abstr. 13761 of 1959). G.I.W.Llewellyn

**7496 MICROWAVE ZEEMAN EFFECT OF FREE HYDROXYL RADICALS.** H.E.Radford.

Phys. Rev. (USA), Vol. 122, No. 1, 114-30 (April 1, 1961).

Paramagnetic resonance absorption at 3 cm wavelength was observed in the products of an electric discharge in low-pressure  $H_2O$  and  $D_2O$  vapour. The spectra are of the electric dipole type, and arise from  $\Lambda$ -type doubling transitions in low-lying rotational levels of the free  $O^1H$  and  $O^1D$  radicals. The theory of the Zeeman effect in  $\Pi$  levels of light diatomic radicals is extended to the general intermediate coupling case, and is used for a detailed analysis of the observed spectra. Numerical results of this analysis include molecular g factors precise to within 3 parts in  $10^5$ , and magnitudes of the  $\Lambda$ -type doubling intervals in several low rotational levels. The measured g factors are compared with theory, including small corrections for molecular rotation, the anomalous spin magnetic moment of the electron, and estimated relativistic effects. This comparison yields the value  $0.67 \pm 0.01$  for the molecular matrix element  $(\Pi|L_y|\Sigma)$ , and also brings to light serious discrepancies between the present experimental results and earlier measurements of the  $\Lambda$ -type doubling in OH and OD. The paramagnetic resonance spectra also exhibit hyperfine structure, from which are derived molecular constants that describe the distribution of unpaired electrons about the H or D nucleus.

**7497 DIPOLE MOMENT OF THE OH RADICAL FROM THE STARK EFFECT OF ITS MICROWAVE SPECTRUM.**

R.T.Meyer and R.J.Myers.

J. chem. Phys. (USA), Vol. 34, No. 3, 1074-5 (March, 1961).

A preliminary value of  $1.65 \pm 0.25 \text{ D}$  is obtained for the electric dipole moment. A parallel-plate waveguide cell, with microwave excitation by dielectric rods, was employed to study Stark effects in the  $\Lambda$ -type doublet transitions at 23 820 Mc/s (see Abstr. 3626 of 1956). The theory of the frequency-displacements is discussed, and expressions are given for the cases where the quantum number F equals  $(J \pm \frac{1}{2})$ . Individual Stark components were not resolvable but the results were analysed through the shifts of maximum absorption in conjunction with appropriate averaging. The electric dipole moment found is close to the bond-moment in water, and outside the range (2.1-2.7D) of the best calculated values (see Abstr. 6179 of 1959). J.Sherick

**7498 FORMATION OF FREE RADICALS IN TRITIATED  $H_2O$  AND  $D_2O$  ICE.**

J.Kroh, B.C.Green and J.W.T.Spinks.

Science (USA), Vol. 133, 1082 (April 7, 1961).

By using tritium as an internal source of radiation, electron spin resonance spectra may be obtained for samples contained in glass without the usual disturbing effects due to irradiated glass. The production of OH and OD radicals in tritiated  $H_2O$  and  $D_2O$  ice may be readily demonstrated with this technique.

**IONIZATION AND DISSOCIATION OF  $H_2$ ,  $N_2$  AND CO IN CHARGE EXCHANGE COLLISIONS WITH POSITIVE IONS.** See Abstr. 7022

**7499 THE CRITICAL VOLUMES AND MOLECULAR DIMENSIONS OF ORGANIC COMPOUNDS.** J.F.Joliet.

C.R. Acad. Sci. (France), Vol. 252, No. 1, 116-18 (Jan. 4, 1961). French.

Relations are given for the critical volumes of molecules. The calculated values are in good agreement with experimental data for simple substances such as  $H_2O$ ,  $SO_2$ ,  $NH_3$ , CO etc. The relations are extended to include saturated linear hydrocarbons and benzene. W.J.Orville-Thomson

7500 TRIMETHYLENE OXIDE. II. STRUCTURE, VIBRATION-ROTATION INTERACTION, AND ORIGIN OF POTENTIAL FUNCTION FOR RING-PUCKERING MOTION. S.I.Chan, J.Zinn and W.D.Gwinn. J. chem. Phys. (USA), Vol. 34, No. 4, 1319-29 (April, 1961).

For Pt I, see Abstr. 2322 of 1961. Further analysis of the data has enabled the molecular structure to be calculated. The structural parameters deduced from the rotational constants are:  $r(C-C) = 1.549 \pm 0.003$  Å,  $r(C-O) = 1.449 \pm 0.002$  Å,  $r(C\alpha-H\alpha) = 1.091 \pm 0.002$  Å,  $r(C\beta-H\beta) = 1.100 \pm 0.003$  Å,  $\angle C\alpha-C\beta-C\alpha = 84^\circ 33' \pm 1'$ ,  $\angle C\alpha-O-C\alpha = 91^\circ 59' \pm 7'$ ,  $\angle C\beta-C\alpha-O = 91^\circ 44' \pm 3'$ ,  $\angle H\alpha-C\alpha-H\alpha = 110^\circ 18' \pm 10'$ ,  $\angle H\beta-C\beta-H\beta = 110^\circ 44' \pm 3'$ . The  $\alpha$ -methylene planes are slightly deflected towards the oxygen atom away from the bisectors of the  $\angle C\beta-C\alpha-O$ 's. However, the actual angle of deflection is rather uncertain. Using these structural parameters, models have been constructed to calculate the vibration-rotation interaction due to the ring-puckering vibration. The experimentally observed rotational constant variations were found to be very well reproduced if the out-of-plane bending motion is assumed to follow a curvilinear path without any stretching of the C-C and C-O bonds. The potential function is also interpreted in terms of force fields within the molecule.

7501 DIPOLE MOMENT OF LITHIUM HYDRIDE. F.A.Matsen.

J. chem. Phys. (USA), Vol. 34, No. 1, 337-8 (Jan., 1961). The dipole moment of lithium hydride is calculated using various *ab initio* calculations of the electronic ground state of LiH. The values all lie between 5.6 and 6.3 D. The measured value of the dipole moment was found to be 5.9 D. T.E.Peacock

7502 ENERGY TRANSFER BETWEEN TRIPLET STATES DETECTED BY ELECTRON SPIN RESONANCE SPECTROSCOPY. J.B.Farmer, C.L.Gardner and C.A.McDowell. J. chem. Phys. (USA), Vol. 34, No. 3, 1058-9 (March, 1961).

When a glassy solution of a mixture of benzophenone and naphthalene in *e.p.a.* at 77°K was irradiated with ultraviolet light which excited the triplet state of benzophenone, the electron spin resonance of the naphthalene triplet state could be detected, confirming that a transfer of excitation energy can take place between the two molecules. E.F.W.Seymour

7503 INTERMOLECULAR POTENTIAL FUNCTIONS FOR NONPOLAR MOLECULES. D.D.Konowalow and J.O.Hirschfelder.

Phys. of Fluids (USA), Vol. 4, No. 5, 629-36 (May, 1961). The Morse potential function is used to represent the intermolecular potential for several nonpolar substances. The potential constants are determined from a combination of crystal structure and second virial coefficient data for Ne, Ar, Kr, Xe, CH<sub>4</sub>, and N<sub>2</sub>. Over a wide temperature range the theoretical second virial coefficients determined from the Morse potential for these substances agree very well with experimental data and are quite comparable with calculations using the Buckingham (exp-6) or the Lennard-Jones (12-6) potentials. For Kr, it is found that the agreement with the experimental second virial coefficients is greatly improved by dividing the intermolecular potential into two separate Morse functions, one applicable where the potential is negative and the other applicable where the potential is positive.

7504 CONFIGURATION AND FREE ENERGY OF A POLYMER MOLECULE WITH SOLVENT INTERACTION. M.E.Fisher and B.J.Hiley.

J. chem. Phys. (USA), Vol. 34, No. 4, 1253-67 (April, 1961). The lattice model of a polymer molecule with excluded volume and nearest-neighbour forces arising from polymer-solvent interaction is investigated by exact numerical calculation for short chains of up to about ten links. Extrapolation to large values of  $n$ , the number of links, is shown to be justified and enables the mean configuration, free energy, entropy, and internal energy to be evaluated as functions of the number of links and of temperature for both poor and "super-perfect" solvents. The mean square end-to-end distance is found to vary according to  $\langle r_n^2 \rangle \cong An^\gamma$ , in agreement with Wall et al., but  $\gamma = \gamma(\eta)$  is a decreasing function of the nearest-neighbour interaction parameter  $\eta = \exp[-V_0/kT]$ . For the three-dimensional simple cubic lattice  $\gamma(0) \cong 1.37$ ,  $\gamma(1) \cong 1.20$  and Flory's theta point, defined by  $\gamma = 1$ , occurs at  $\eta \cong 1.48$ . For the two-dimensional square lattice  $\gamma(0) \cong 1.57$ ,  $\gamma(1) \cong 1.47$ , and  $\eta\theta \cong 2.0$ . The fractional variance of the distribution of  $r_n^2$  is found to be appreciably smaller than the corresponding Gaussian value. Numerical data and graphs are presented for the free energy, entropy, and internal energy as functions of  $\eta$ .

7505 MOLECULAR THEORY OF RELAXATION PHENOMENA IN POLYMERS. O.Nakada and Y.Chikahisa. Suppl. Progr. theor. Phys. (Japan), No. 10, 36-55 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The development of the molecular theory of configurational relaxation phenomena in polymers is briefly reviewed with the emphasis on the method of generalized diffusion equation and Rouse's model (Abstr. 5872, 6510 of 1953). Various dispersion phenomena in polymeric systems such as of dynamic viscosity, of dynamic Young's modulus and of dynamic bulk modulus are elucidated on the basis of the model. The present theoretical situation of the dispersion phenomena in crystalline polymers is also discussed.

RELAXATION PHENOMENA OF POLYMERS. See Abstr. 6449

7506 GENERAL THEORY OF RELAXATIONS IN THE POLYMER CHAIN. A.Miyake.

Suppl. Progr. theor. Phys. (Japan), No. 10, 56-72 (1959). "Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The nature of the Fokker-Planck equation proposed by Kirkwood, for the distribution function of polymer chain configuration is investigated in detail. The average coordinates equation and thermodynamic laws are derived from this diffusion equation. The thermodynamic formulation is deduced with the aid of the introduction of affinities. The solution of the diffusion equation is given in terms of the eigenfunction of a self-adjoint operator derived from the original diffusion equation according to Kirkwood's theory. The relations between excitation function, relaxation function and response function are shown to be reflections of similar relations among the distribution functions themselves, and the correlation function is calculated. The irreversible entropy production is given in terms of the relaxation time spectrum. The Rouse chain is investigated as an illustration.

7507 EXPECTED SQUARE OF THE LENGTH OF ISOTACTIC VINYLIC HYDROCARBON-TYPE CHAINS. V.E.Meyer, J.B.Kinsinger and P.M.Parker.

J. chem. Phys. (USA), Vol. 34, No. 4, 1429-33 (April, 1961). The mean square length of long isotactic vinyl hydrocarbon-type chains is calculated. The Markov chain formalism is employed for this calculation. The problem of excluded volume is not considered.

7508 MOLECULAR BEAM ELECTRON BOMBARDMENT DETECTOR. R.Weiss.

Rev. sci. Instrum. (USA), Vol. 32, No. 4, 397-401 (April, 1961). A molecular beam electron bombardment detector that detects approximately 1/40 of a neutral beam falling into an area of  $3 \times 10^{-2}$  cm<sup>2</sup> is described. Molecular beams of sulphur dioxide and argon have been detected with signal-to-noise ratios of 2000/1 and 500/1, respectively. An improved design is discussed.

7509 THEORY OF MOLECULAR BEAM FORMATION WITH LONG CHANNELS. G.Becker.

Z. Phys. (Germany), Vol. 162, No. 3, 290-312 (1961). In German. According to a theory of Giordmaine and Wang (Abstr. 7825 of 1960) concerning the formation of molecular beams by long parallel tubes, the peak beam intensity  $j$  should be proportional to  $N^{1/2}$  ( $N$  = gas flow rate). This is in contradiction to the author's experimental results on NH<sub>3</sub> molecular beams revealing  $j$  proportional to  $N^{2/3}$  a wide range of flow rates. It is shown that this relation equally represents the experimental results of Giordmaine and Wang with CO<sub>2</sub> molecular beams. The measured directivities are smaller than the theoretical values and the departures increase with decreasing flow rate and tube diameter. The theory of Giordmaine and Wang is extended by considering the choking effects of the tube orifices. Another relatively simple theoretical procedure for the evaluation of the directivity of tubes is given using the concept of an "effective tube length". By this method the directivities of several differently formed tubes and of composite beam sources are calculated and compared with the experimental results. The evaluations confirm the experimental observation that sources which are composed of tubes are in practice not superior to those which consist of a few slits, the slit width being equal to the tube diameter. Then the remaining discrepancy between the theoretical and experimental results is partly overcome by using the total impact cross-section in place of the gas kinetic one. The influence of surface diffusion on the tube walls and the effect of the gas cloud in front of the source on the beam formation are discussed.

# SOLID-STATE PHYSICS

## SOLID-STATE RESEARCH AT LOW TEMPERATURES.

### 7510 I. INTRODUCTION. J.Volger.

Philips tech. Rev. (Netherlands), Vol. 22, No. 6, 190-5 (1960-61)

Shows by a number of examples that a system may be said to be at a low temperature when  $kT$  is smaller than a certain characteristic energy. This is the energy quantum  $h\nu$  for the specific heat of a system of quantized harmonic oscillators, the heat of fusion (per mole) for the fusion of a solid, the energy  $\mu_B H$  for the magnetization of a paramagnetic substance, and the Fermi energy  $E_F$  for the electrical conductivity of metals and semiconductors. The article concludes with the remark that many solid-state processes, e.g. the orientation of electron spins in a paramagnetic substance, are slowed down at low temperature.

## SOLID-STATE RESEARCH AT LOW TEMPERATURES.

### 7511 II. ELECTRON CONDUCTION IN METALS AND SEMICONDUCTORS. J.Volger.

Philips tech. Rev. (Netherlands), Vol. 22, No. 7, 226-31 (1960-61).

The residual resistance shown by a metal at extremely low temperature is due to the scattering of the electrons by lattice imperfections. Plastic-deformation experiments on highly purified aluminium give a picture of the individual influence of point defects and dislocations. The magnetoresistance of copper is found to obey Kohler's rule only in so far as the residual resistance is due to point defects in the lattice; dislocations cause a deviation from this rule. The residual resistance of iron contaminated with carbon is proportional to the carbon concentration but not entirely independent of temperature (as it should be to obey Matthiessen's rule). The fact that the superconducting transition temperature depends on an external magnetic field is turned to use in a switching element made of vapour-deposited tantalum. In some extrinsic semiconductors, conduction occurs at low temperature as a result of the mechanism whereby the electrons jump directly from one donor to the other (impurity band conduction).

### 7512 CLUSTER SIZE IN RANDOM MIXTURES AND PERCOLATION PROCESSES. C.Domb and M.F.Sykes.

Phys. Rev. (USA), Vol. 122, No. 1, 77-8 (April 1, 1961).

It is pointed out that the topological problem which arises in the theory of critical concentration in ferromagnetic crystals, and discussed recently by Elliott et al. (Abstr. 1200 of 1961) is identical with a problem arising in the statistical theory of random mixtures. Additional terms of series expansions are given, and these enable improved estimates of the critical concentration to be made. A distinction is drawn between "site mixtures" and "bond mixtures", the latter having been previously considered under the heading of "percolation processes". The critical concentrations for the two problems are usually different. Some rigorous results regarding the critical concentrations are quoted.

### 7513 A MICROSCOPIC DERIVATION OF THE BORN-HUANG RELATIONS BETWEEN THE ATOMIC FORCE CONSTANTS. L.T.Hedin.

Ark. Fys. (Sweden), Vol. 18, Paper 25, 369-78 (1960).

Born and (Abstr. 1354 of 1941) Huang (Abstr. 9034 of 1950) have derived a general relation between the elastic constants and the atomic force constants by considering long acoustic waves in an infinitely large lattice. The symmetry properties of the elastic constants lead to certain linear relations between the atomic force constants that could not be predicted from a microscopic treatment. It is shown here that by taking the finite extension of the lattice into account the Born-Huang relations readily follow in the microscopic treatment.

### 7514 SOME CALCULATIONS FOR A ONE-DIMENSIONAL SALT MIXTURE. M.Blander.

J. chem. Phys. (USA), Vol. 34, No. 2, 697-8 (Feb., 1960).

Calculations on the importance of long-range interactions in ionic mixtures based on a one-dimensional model indicate a physical basis for the observed negative deviations from ideality.

W.J.Orville-Thomas

### 7515 EIGENFUNCTIONS FOR INTEGER AND HALF-ODD INTEGER VALUES OF J SYMMETRIZED ACCORDING TO THE ICOSAHEDRAL GROUP AND THE GROUP $C_{3v}$ . A.G.McLellan.

J. chem. Phys. (USA), Vol. 34, No. 4, 1350-9 (April, 1961).

Eigenfunctions of  $J^2$  for  $J = 0, \frac{1}{2}, 1, \dots, 8$ , are obtained and tabulated

which are symmetrized according to the icosahedral group and the group  $C_{3v}$ , in terms of eigenfunctions of  $J^2$  and  $J_z$ , referred to a fivefold axis of rotation as the  $z$  axis. The functions are symmetrized according to  $C_{3v}$  in such a way that the symmetry operation of a  $2\pi/3$  rotation is represented by a diagonal matrix. The results are applied to calculate the anisotropic magnetic splitting factors for the doublet states arising from the above symmetry.

### 7516 CUBIC-FIELD SPLITTING AND CUBIC-SYMMETRY ORTHONORMAL SETS OF WAVE FUNCTIONS FOR J MANIFOLDS (J HALF-INTEGER). R.Pappalardo.

J. chem. Phys. (USA), Vol. 34, No. 4, 1380-8 (April, 1961).

Energy level splittings of manifolds characterized by half-integer values of  $J$  are derived in the case of a cubic crystal potential containing fourth- and sixth-order terms. Orthonormal sets of wave-functions in cubic symmetry are tabulated for the same manifolds.

### 7517 CUBIC CRYSTAL FIELD SPLITTING OF THE $Gd^{3+}$ ION. R.Lacroix.

Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 550-1 (Feb., 1961).

### 7518 NUCLEAR ORIENTATION OF PARAMAGNETIC IMPURITY IONS. M.Kaplan and D.A.Shirley.

Phys. Rev. Letters (USA), Vol. 6, No. 7, 361-2 (April 1, 1961).

A substantial extension of the Gorter-Rose technique of nuclear orientation (Abstr. 1510, 2047 of 1949) would result if nuclei of all elements which form paramagnetic ions could be oriented in this way. It is pointed out that this extension is made possible by incorporating the ions as impurities into single crystals of cerium magnesium nitrate. The impurities may be interstitial or they may be trapped in tiny "brine holes". In either case they should be in thermal equilibrium with the lattice after demagnetization and can be polarized in fields of several hundred oersteds at temperatures below  $0.01^\circ K$ . This hypothesis is tested using  $Cr^{51}$  impurities.

J.M.Baker

### 7519 SURFACE ENERGY AND CONFIGURATION OF INERT GAS CRYSTALS. I. H.H.Schmidt and G.Jura.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 60-6 (Nov., 1960).

An expression is derived for the average potential energy of a particle at any given distance above the plane face of a semi-infinite crystalline array of similar particles obeying an inverse power, pairwise additive potential function with spherical symmetry. This expression is then used with a Lennard-Jones potential function to discuss various models for the surface configuration of semi-finite crystals by comparing the minimum excess surface energy of the model with that of the undistorted half-crystal. The results indicate that the only likely distortion in the surface of the static lattice at  $0^\circ K$  is a slight expansion normal to the surface as indicated by Shuttleworth's calculations (see Abstr. 2201 of 1949).

### 7520 THE GRAIN BOUNDARY ENERGY AND CONFIGURATION OF INERT GAS CRYSTALS. II.

H.H.Schmidt and G.Jura.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 67-70 (Nov., 1960).

The expression derived in the Pt I (see preceding abstract) for the average inverse power potential energy of interaction between a particle at a fixed distance above a half-crystal face and the half-crystal is applied to a calculation of the minimum energy spacing and interfacial energy between two perfect half-crystals placed together to form a "completely misfitting" grain boundary. The grain boundary energies and spacings of various juxtaposed surfaces of face-centred cubic argon at  $0^\circ K$  are calculated as examples with the following results in ergs/cm<sup>2</sup>: (100)-(110), 41.7; (100)-(111), 22.8; (111)-(111), 16.0. This method would seem to be applicable to any system obeying the specified type of potential function when there is a continuous spontaneous generation of dislocations in two dimensions at the boundary as appears to be the case for large angle twist or tilt boundaries.

### 7521 SURFACE STATES OF ONE-DIMENSIONAL CRYSTALS. I. E.Aerts.

Physica (Netherlands), Vol. 26, No. 12, 1047-56 (Nov., 1960).

Energy levels at the surface of a one-dimensional semi-finite crystal are calculated by means of the scattering matrix method of Saxon and Hutner (Abstr. 6555 of 1949) in the case when the potential of the surface atom is asymmetric. By proceeding in this way,

Tamm's formula (1932) was obtained. Analogous calculations for a linear crystal with a surface contaminated by an impurity atom were also made. The same number of possible solutions is found as in the previous case i.e. two, one or none, but the position of the levels is different. An explanation for the n-type or p-type surface conductivity of an intrinsic semiconductor crystal is proposed.

#### 7522 SURFACE STATES OF ONE-DIMENSIONAL CRYSTALS. II. E.Aerts.

Physica (Netherlands), Vol. 26, No. 12, 1057-62 (Dec., 1960).

A semi-infinite crystal model composed of two kinds of atoms is considered in both ionic and valence crystals. It is assumed that the potential of the atoms at the surface is asymmetric. It is proved that the number and the position of the localized surface states is affected by the lattice constant, by the atomic potential strength of the two different kinds of atoms and by the step in potential energy at the surface. The position of the levels is calculated by the scattering matrix method of Saxon and Hutner for various numerical values of the parameters mentioned above. Generally, only one level is found in the first forbidden energy gap; exceptionally two or none. The calculations are restricted to a crystal with a clean surface.

#### 7523 SURFACE STATES OF ONE-DIMENSIONAL CRYSTALS. III. E.Aerts.

Physica (Netherlands), Vol. 26, No. 12, 1063-72 (Dec., 1960).

Localized surface energy levels are computed by the scattering matrix method of Saxon and Hutner for crystal models with a symmetric potential for the surface atom. In the case of a clean surface, no levels are found in accordance with the results of Shockley (1939). If, however, the surface is covered with an adsorbed impurity, surface levels are found in the case that the potential of the impurity is weaker than that of the bulk atoms. Theoretical evidence is given for the existence of interface states at the junction of two semi-infinite one-dimensional crystals. They only occur when the first forbidden energy gap of one of them corresponds with the second forbidden energy gap of the other.

#### 7524 EXCHANGE POLARIZATION AND THE MAGNETIC INTERACTIONS OF RARE EARTH IONS.

R.E.Watson and A.J.Freeman.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 277-80 (March 15, 1961).

Describes a result of a spin-polarized Hartree-Fock calculation (see Abstr. 20769 of 1960) on  $Gd^{3+}$ ; the outermost region of the ion carries a spin antiparallel to the net spin, which might be the cause of the abnormal hyperfine interactions in  $GdF_3$  and of the negative Knight shift in  $GdAl_2$ . An error in Figure 1, concerning the omission of the 5p spin density from a plot of  $(\rho_t - \rho_i)$ , is corrected in an Erratum, *ibid.*, Vol. 6, No. 7, 388 (April 1, 1961).

J.Hawgood

## LATTICE MECHANICS

#### 7525 STUDY OF THE [LATTICE] DYNAMICS OF SOLID AND OF LIQUID MEDIA BY SLOW NEUTRON SPECTROMETRY. G.P.Felcher and M.Musci.

Energia Nucleare (Italy), Vol. 7, No. 11, 772-92 (Nov., 1960). In Italian.

The paper deals with some facts concerning inelastic scattering of slow neutrons by solids and liquids. A short outline is given of the basic concepts of the theory of neutron-phonon interaction, and the most significant experiments on this topic are reviewed.

#### 7526 THE ENERGY THEOREM IN MAGNETO-ELASTICITY. G.Crupi.

Atti Semin. Mat. Fis. Univ. Modena (Italy), Vol. 9, 47-58 (1959-60). In Italian.

An energy theorem is derived for the equations (see Abstr. 8026 of 1957) describing an electrically conducting elastic solid coupled to the electromagnetic field. The energy flux is the sum of the Poynting vector and a term describing the flux of elastic energy. The special case of a transverse wave propagating parallel to a uniform applied magnetic field in a homogeneous isotropic solid is considered in detail, and in this particular case the velocity of energy propagation coincides with the wave and group velocities.

O.Penrose

#### 7527 NONEQUILIBRIUM PROCESSES IN ISOTOPICALLY DISORDERED CRYSTALS. A.A.Maradudin.

J. math. Phys. (USA), Vol. 2, No. 3, 349-69 (May-June, 1961).

The equations of motion of the atoms in an isotopically disordered crystal, which contains a fraction  $p$  of atoms of mass  $M_1$ , and a fraction  $1 - p$  of atoms of mass  $M_2$ , are expanded in terms of the normal coordinates of a monatomic lattice whose atoms all have mass  $M = pM_1 + (1 - p)M_2$ . The equations of motion of these normal coordinates are derived and are then solved by Laplace transform methods. The perturbed normal coordinates are found to decay exponentially into the future and into the past until an inverse power dependence on time becomes dominant. Calculations of the mean lifetime and frequency shift of each normal coordinate are carried out for the one-dimensional case. A theory of the optical absorption spectrum of an isotopically disordered ionic crystal is obtained, and the distribution function for the energies of the normal modes and the mean energy in a normal mode are found. The generalization of the methods of this paper to three-dimensional lattices is discussed. See also following abstract.

#### 7528 NONEQUILIBRIUM PROCESSES IN ISOTOPICALLY DISORDERED CRYSTALS. DEPENDENCE ON DEGREE OF ORDER. R.Zwanzig.

J. math. Phys. (USA), Vol. 2, No. 3, 370-2 (May-June, 1961).

A previous paper (see preceding abstract) has shown that approximate normal modes of isotopically disordered crystals decay irreversibly when the arrangement of isotopes is completely random. These results are generalized to crystals with an arbitrary degree of order. In particular, it is shown irreversible behaviour occurs whenever the spatial correlation between isotopic species extends over a fixed finite range, as the size of the crystal tends to infinity.

#### 7529 THE VIBRATIONS OF CERTAIN ONE-, TWO-, AND THREE-DIMENSIONAL LATTICES.

B.C.De Loach, Jr and W.H.Shaffer.

J. molecular Spectrosc. (USA), Vol. 6, No. 2, 229-37 (Feb., 1961).

The "Lagrange's equations with extra forces" technique is applied to vibrational problems of certain lattice types. Justification is obtained for some of the "boundary" assumptions usually made in the study of large crystals. In the limit of large numbers of particles closed expressions are obtained for the normal frequencies for the linear chain of identical point masses with nearest and next nearest neighbour coupling, the linear chain of alternating point masses with nearest and next nearest neighbour coupling, and a special type of two and three dimensional lattice.

#### 7530 VIBRATIONAL SPECTRUM OF GOLD.

S.K.Joshi and M.P.Hemkar.

Phys. Rev. (USA), Vol. 122, No. 1, 13-14 (April 1, 1961).

A theoretical lattice-vibration spectrum is calculated on the basis of a three-force-constant model as elaborated by Bhatia (Abstr. 3257, 6996 of 1955). The lattice specific heat is calculated and compared with the experimental data.

#### 7531 ANHARMONIC ATTENUATION OF LOCALIZED LATTICE VIBRATIONS. P.G.Klemens.

Phys. Rev. (USA), Vol. 122, No. 2, 443-5 (April 15, 1961).

Lattice modes localized about defects can interchange energy with the continuum of lattice waves by anharmonic interactions. The relaxation time of a localized mode is calculated, taking account of cubic anharmonicities and using perturbation theory analogous to the treatment of three-phonon interactions. At zero temperature the relaxation time is typically of the order of 100 periods, but decreases with increasing temperature.

#### 7532 THERMAL MOTION IN PALLADIUM HYDRIDE STUDIED BY MEANS OF ELASTIC AND INELASTIC SCATTERING OF NEUTRONS. J.Bergsma and J.A.Goedkoop.

Physica (Netherlands), Vol. 26, No. 9, 744-50 (Sept., 1960).

A single crystal neutron diffraction investigation of electrolytically loaded palladium hydride of composition  $PdH_{0.63}$  confirms the NaCl-type arrangement found previously for material loaded from the gas phase. The root mean square displacements due to thermal motion of the palladium and hydrogen atoms at room temperature are found to be  $0.10 \pm 0.01$  and  $0.24 \pm 0.02$  Å, respectively. Measurements of the total neutron scattering cross-section as a function of neutron energy and of the energy distribution of 0.004 eV neutrons scattered at  $90^\circ$  are reported and interpreted in terms of an Einstein model for the proton vibrations with a fundamental frequency corresponding to  $0.056 \pm 0.002$  eV. From this the root mean square displacement of the protons relative to the palladium

sublattice at room temperature is estimated to be  $0.22 \pm 0.02$  Å, in agreement with the values found by diffraction. The cold neutron scattering data also give information about the heat motion of the palladium atoms. Interpreted on a Debye model they yield a Debye temperature of  $300 \pm 25^\circ\text{K}$  and a root mean square displacement of  $0.10 \pm 0.01$  Å.

ULTRASONIC VELOCITY IN 6 LOW MELTING POINT ORGANIC SOLIDS. See Abstr. 6857

#### 7533 A NEW DERIVATION OF THE NON-EQUILIBRIUM DISTRIBUTION FUNCTION FOR SEMICONDUCTORS.

A.G.Samoilovich, M.I.Klinger and L.L.Korenblit.  
Fiz. tverdogo Tela (USSR), Sbornik [Supplement] II, 121-35 (1959). In Russian.

Using the statistical mechanics of irreversible processes (Abstr. 8437 of 1957), the non-equilibrium energy distribution function is derived for electrons in a non-degenerate semiconductor. A.Tybulewicz

#### 7534 THE EFFECT OF ANISOTROPY OF A $\text{Bi}_2\text{Te}_3$ MONO-CRYSTAL ON THE SCATTERING OF ELECTRONS BY ACOUSTIC PHONONS. A.G.Samoilovich and M.I.Klinger.

Fiz. tverdogo Tela (USSR), Sbornik [Supplement] II, 143-57 (1959). In Russian.

Uses the results of an earlier paper (see preceding abstract) to show that the anisotropy of electron scattering on acoustic phonons is slight and that it is due to the anisotropy of the deformational potential constants. The dependence of the relaxation time tensor components on the electron energy is the same as in the case of isotropic scattering. In spite of the anisotropy of scattering and of effective masses, thermo-e.m.f.'s are strictly isotropic in the case of scattering of electrons by phonons. A.Tybulewicz

A CLASSICAL INTERACTION BETWEEN THE LATTICE VIBRATIONS AND THE COLLECTIVE OSCILLATIONS OF THE ELECTRON GAS IN CRYSTALS. See Abstr. 7561

## Thermal Properties

### THERMAL PROPERTIES OF LITHIUM HYDRIDE.

See Abstr. 7697

#### 7535 CHANGE OF SPECIFIC HEAT OF METALS DURING PLASTIC DEFORMATION.

B.V.Belogurov and L.M.Shestopalov.  
Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 4, 734-8 (1958). In Russian.

The authors made systematic measurements of the specific heat of iron and copper during plastic deformation of up to 10% at temperatures between 20 and  $50^\circ\text{C}$ . A directly heated differential vacuum calorimeter was used with an annealed deformed specimen as a control. The sensitivity of the apparatus was better than 0.1%. The results from 400 specimens showed that the specific heat increases by ~0.5% for 10% axial extension or compression for both iron and copper. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 4, 150-4 (1959)].

M.G.Priestley

#### 7536 EFFECT OF MAGNETIC CLUSTERS ON THE SPECIFIC HEAT OF Ni-Cu AND Fe-V ALLOYS. K.Schröder.

J. appl. Phys. (USA), Vol. 32, No. 5, 880-2 (May, 1961).

Experiments with Ni-Cu and Fe-V alloys indicate that the specific heat at low temperature cannot be described by electronic and lattice terms alone. An attempt is made to explain an additional term in the specific heat of these alloys on the basis of ferromagnetic clusters.

#### 7537 HEAT CAPACITY ANOMALY IN SOLID AIR.

W.H.Lien and N.E.Phillips.  
J. chem. Phys. (USA), Vol. 34, No. 3, 1073-4 (March, 1961).

In the temperature range  $1^\circ\text{--}4^\circ\text{K}$  the heat capacity of solid air is as much as 400 times greater than that of solid oxygen. Its variation with temperature in this range is shown. An explanation is discussed that the large heat capacity is associated with an anti-ferromagnetic ordering of the electron spins of the oxygen molecules at about  $3^\circ\text{K}$ . W.Good

#### 7538 HEAT CAPACITIES AND THERMODYNAMIC FUNCTIONS OF $\text{ZrH}_2$ AND $\text{ZrD}_2$ FROM 5 TO $350^\circ\text{K}$ AND THERMODYNAMIC VIBRATION FREQUENCY IN $\text{ZrH}_2^*$ .

H.E.Floto and D.W.Osborne.

J. chem. Phys. (USA), Vol. 34, No. 4, 1418-25 (April, 1961).

The heat capacities of  $\text{ZrH}_2$  and  $\text{ZrD}_2$  were measured in an adiabatic type calorimeter from 5 to  $350^\circ\text{K}$ . X-ray analyses show the hydrides consist of a single face-centred tetragonal phase. The data for both compounds below  $11^\circ\text{K}$  were found to fit the equation  $C_V = 9.8 \times 10^{-4}T + 464.6(T/\theta)^3 \text{ cal deg}^{-1} \text{ mole}^{-1}$ , where  $\theta = 311.4^\circ\text{K}$ , and this equation was used to extrapolate the heat capacities below  $6^\circ\text{K}$ . Between 20 and  $100^\circ\text{K}$  the  $C_p$  of  $\text{ZrD}_2$  averages 1% lower than that of  $\text{ZrH}_2$  but above  $110^\circ\text{K}$  the  $C_p$  of  $\text{ZrD}_2$  becomes increasingly greater than that of  $\text{ZrH}_2$ . At  $298.15^\circ\text{K}$  the heat capacities and thermodynamic functions calculated from the data are  $C_p = 7.396 \pm 0.015 \text{ cal deg}^{-1} \text{ mole}^{-1}$ ,  $S^\circ = 8.374 \pm 0.02 \text{ cal deg}^{-1} \text{ mole}^{-1}$ ,  $H^\circ - H_0^\circ = 1284.1 \pm 2 \text{ cal mole}^{-1}$ , and  $(F^\circ - H_0^\circ)/T = -4.067 \pm 0.01 \text{ cal deg}^{-1} \text{ mole}^{-1}$  for  $\text{ZrH}_2$ , and  $9.631 \pm 0.019$ ,  $9.168 \pm 0.02$ ,  $1474.4 \pm 3$  and  $-4.223 \pm 0.01$ , respectively, for  $\text{ZrD}_2$ . The free energy of formation of  $\text{ZrH}_2$  at  $298.15^\circ\text{K}$  is  $-30.9 \pm 2 \text{ kcal mole}^{-1}$  and that of  $\text{ZrD}_2$  is  $-31.2 \pm 2$ . On the assumption that the difference in the heat capacity between the two isotopic compounds arises from a triply degenerate hydrogen vibration, it was found that the difference in the temperature range 100 to  $350^\circ\text{K}$  could be satisfactorily fitted by the difference between two Einstein heat capacity functions with a frequency of  $1190 \pm 30 \text{ cm}^{-1}$  for  $\text{ZrH}_2$  and  $1190/\sqrt{2} \text{ cm}^{-1}$  for  $\text{ZrD}_2$ . This result is compared with the optical lattice vibration frequency found by neutron scattering experiments.

#### 7539 SPECIFIC HEAT OF YTTRIUM IRON GARNET FROM $1.5^\circ$ TO $4.2^\circ\text{K}$ . S.S.Shinozaki.

Phys. Rev. (USA), Vol. 122, No. 2, 388-9 (April 15, 1961).

Two samples were examined. The data are analysed into lattice- and spin-wave contributions characterized, respectively, by the Debye temperatures  $\Theta_1 = 538^\circ\text{K}$ ,  $\Theta_2 = 567^\circ\text{K}$ , and by  $D_1 = 0.81 \times 10^{-28} \text{ erg cm}^2$ ,  $D_2 = 0.85 \times 10^{-28} \text{ erg cm}^2$ , where  $D$  is defined by the dispersion relation for spin waves,  $\hbar\omega = Dk^2$ .

#### 7540 THE DEBYE TEMPERATURE OF ICE.

A.Kahane.

C.R. Acad. Sci. (France), Vol. 252, No. 5, 678-80 (Jan. 30, 1961). In French.

Specific heat data between 10 and  $20^\circ\text{K}$  (Abstr. 11579 of 1960) indicate a Debye temperature of  $192^\circ$  for ice. Taking elastic constants into consideration, Debye temperatures of  $127^\circ$  and  $194^\circ$  are found respectively for the hexagonal and cubic forms of ice.

H.H.Hodgson

#### THE PROPAGATION OF HEAT IN SOLIDS.

R.Lucas.

C.R. Acad. Sci. (France), Vol. 252, No. 6, 852-4 (Feb. 6, 1961). In French.

Thermal conduction in solids is discussed in terms of elastic waves. It is pointed out that, with a temperature gradient, dispersion of the waves occurs and the associated energy flow is no longer rectilinear. In the case of microcrystalline solids it is predicted that this will lead to an additional heat flow against the temperature gradient. This is expected to produce observable boundary effects and the general suggestion is made that known anomalies may be explained.

J.W.Lee

#### 7542 THERMAL CONDUCTIVITY IN $\text{Li}_2\text{Ni}_{(1-x)}\text{O}$ . S.van Houten.

Philips Res. Rep. (Netherlands), Vol. 15, No. 5, 433-6 (Oct., 1960).

The conductivity as a function of lithium concentration was measured and interpreted in terms of phonon-impurity scattering. A linear relationship is found between the mean free path for phonon-impurity scattering and the mean Li-Li distance in the lattice. This result resembles Kittel's theory about glasses, but is not in agreement with Klemens's equation for scattering at point imperfections. The substance is further found not to be as useful a material for thermoelectric generation as was suggested by other authors.

#### 7543 LATTICE THERMAL CONDUCTIVITY OF GERMANIUM-SILICON ALLOY SINGLE CRYSTALS AT LOW TEMPERATURES. A.M.Toxen.

Phys. Rev. (USA), Vol. 122, No. 2, 450-8 (April 15, 1961).

Thermal conductivity measurements are reported for five single-crystal Ge-Si specimens containing 0-7.56 at. % Si. The measurements were made under steady-state conditions and cover

the temperature range 2-50° K. The experimental results are compared to three theoretical models, those of Berman et al. (Abstr. 9901 of 1960), Callaway (Abstr. 5607 of 1959), and Klemens (Abstr. 7803 of 1951; 2546 of 1956); it is found that the data are best fit by Callaway's model. Good agreement between experimental results and theoretical models is obtained by postulating only three sources of phonon scattering in the specimens: three-phonon processes, isotopic point-defect scattering by the germanium and silicon atoms, and boundary scattering. However, evidence is presented that boundary scattering occurs not only at the external surfaces of the specimens, but also at internal surfaces associated with microscale fluctuations of composition of the type reported by Goss, Benson and Pfann.

#### 7544 LOW-TEMPERATURE LATTICE THERMAL CONDUCTIVITY. J. Callaway.

Phys. Rev. (USA), Vol. 122, No. 3, 787-90 (May 1, 1961).

The effect of point imperfections on lattice thermal conductivity is discussed with particular attention to the case in which the temperature is low, but the normal three-phonon scattering is still dominant. The experimental results of Walker and Fairbank (Abstr. 12549 of 1960) on the conductivity of isotopic mixtures of solid helium are analysed.

## ELECTRON STATES

#### 7545 STRUCTURE OF THE VALENCE BAND OF BISMUTH-TYPE CRYSTALS. E.I. Cheglukov.

Izv. vysshikh uchebnykh zavedenii, Fizika (USSR), 1960, No. 4, 13-21. In Russian.

Uses one-electron approximation and derives the symmetry properties of the valence band of bismuth and the electron energies in that band. A. Tybulewicz

#### 7546 THEORY OF TAMM SURFACE STATES IN APPROXIMATION HIGHER THAN TIGHT-BINDING APPROXIMATION. M. Tomášek and J. Koutecký.

Czech. J. Phys., Vol. 10, No. 4, 268-74 (1960).

The influence of the non-zero value of exchange integrals between Wannier functions, localized in non-neighbouring elementary cells (higher approximation than tight-binding), on the conditions of existence of Tamm surface states and the position of the energy level corresponding to the surface state is shown.

#### 7547 ON THE PROBLEM OF FREE TRANSIT TIME OF HIGH ENERGY ELECTRONS IN METALS.

G.E. Zil'berman and I.O. Kulik.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 9-13 (July, 1960). In Russian.

An analytical study is made of an electron in the band, situated above the conduction zone, for the case when the electron energy is not sufficiently high to excite plasma oscillations, and when the free path is determined only by collisions with the conductivity electrons. It is shown that the free transit time can be increased many times by the limitations imposed on collisions by the zone structure of the spectrum. M.H. Sloboda

#### 7548 SURFACE STATES IN A ONE-DIMENSIONAL PERFECT SEMI-INFINITE CRYSTAL. P. Phariseau.

Physica (Netherlands), Vol. 26, No. 9, 737-43 (Sept., 1960).

Discusses the energy-spectrum of an electron moving in a one-dimensional lattice containing only one type of atom, represented as a Dirac  $\delta$ -function, by means of a Green's-function method in the one-electron approximation. The formula giving the surface energy levels corresponds completely with that given by other authors. It can be proved that by continuous variation of the parameters the extra energy-levels leave the bottom of the energy bands and in this approximation never attain the top of the foregoing energy-band.

#### 7549 EFFECT OF CONFIGURATION MIXING AND COVALENCY ON THE ENERGY SPECTRUM OF RUBY. S. Sugano and M. Peter.

Phys. Rev. (USA), Vol. 122, No. 2, 381-6 (April 15, 1961).

For the purpose of improving a previous analysis (Abstr. 645 of 1960) of the optical and microwave spectrum of ruby, a calculation has been performed in the strong cubic field scheme, taking into account the effect of configuration mixing of the higher excited  $t_2^2 e$  states into the  $t_2^3$  states. In the calculation, covalency of the  $t_2$  and e

electrons is also introduced in a simplified fashion besides the spin-orbit interaction, trigonal field and Zeeman energy. The result shows that configuration mixing and covalency play a very important role in giving zero-field splittings and g values of the  $t_2^3$  states. It is also found that there is not much difference between the degrees of covalency for the  $t_2$  and e electrons, although they are fairly large for both electrons. The best zero-field splitting of the ground state thus obtained in  $0.24 \text{ cm}^{-1}$  with the correct sign.

#### 7550 ELECTRON ENERGY BANDS OF ONE-DIMENSIONAL RANDOM ALLOYS. J.S. Faulkner and J. Korrington.

Phys. Rev. (USA), Vol. 122, No. 2, 390-6 (April 15, 1961).

A method for calculating the density of states for an infinite, one-dimensional random alloy is obtained by investigating the asymptotic behaviour of the trace of the "transmission" matrix which relates the values taken on by the wave-function and its derivative at either end of the crystal. This matrix can be calculated if the potentials of the constituent A and B atoms,  $V_A$  and  $V_B$  are given. The equations are first derived for a very general case, and then the results of a calculation for an alloy in which the A and B atoms have equal concentrations is shown for the case that  $V_A$  and  $V_B$  are  $\delta$ -function potentials. Certain generalizations of the method for treating other nonperiodic problems are discussed briefly.

#### 7551 INFLUENCE OF SPIN ON ELECTRONIC TRANSFORMATIONS.

K.A. Gschneidner, Jr., R.R. McDonald and R.O. Elliott.

Phys. Rev. Letters (USA), Vol. 6, No. 5, 218-20 (March 1, 1961).

Cerium undergoes a transformation of its electron configuration on cooling at atmospheric pressure or on compression at room temperature, as can be shown from its magnetic properties. The influence upon this transition of the addition of 2 at.% of other rare earth solute is described. The depression of the transition temperature at atmospheric pressure appears to depend upon the number of unpaired 4f electrons. However, the elevation of the transition pressure at room temperature appears to depend upon the size of the solute ion. J.M. Baker

#### 7552 WAVE-FUNCTIONS AND ENERGY OF A [CONDUCTION] BAND ELECTRON IN A NaCl CRYSTAL.

K.B. Tolpygo and O.F. Tomasevich.

Ukrayin. fiz. Zh. (USSR), Vol. 3, No. 2, 145-67 (1958). In Ukrainian.

The wave-function of a conduction electron is expressed in the form of a linear combination of quasi-atomic functions  $\chi_1$  and  $\chi_2$ :

$$\Psi = \sum_l [b_1 \chi_1(|r - r_1^l|) e^{i k r_1^l} + b_2 \chi_2(|r - r_2^l|) e^{i k r_2^l}].$$

$\chi_1$  in the vicinity of the nucleus coincides with 3s function of the outermost electron of the Na atom, while  $\chi_2$  in the vicinity of the nucleus is a solution of Schrödinger's equation for an electron with zero energy and with a  $\text{Cl}^-$  ion potential according to Hartree's data. Both functions undergo more rapid damping at great distances from the nuclei and satisfy the condition of orthogonality with respect to the wave-functions of the inner electrons of their ions. The potential energy is expressed by the sum of the Coulomb and exchange potentials of all ions and the polarization energy of the electron shells of adjacent ions by the field of the given electron. The coefficients of the linear combinations were derived by Ritz's method.  $E(k)$  curves were obtained for the two lowest zones. The values of  $E(0)$  and the effective mass  $m^*/m = 0.584$  proved too low, which is evidently due to one's neglecting the condition of orthogonality of the wave-band function of the electron with respect to the function of the inner electrons of the adjacent ions. At  $k = 0$  the probability of the electron being located in the vicinity of the  $\text{Cl}^-$  and  $\text{Na}^+$  ions  $|b_2|^2$  and  $|b_1|^2$  is  $|b_2/b_1|^2 = 1 : 3.036^2 \approx \frac{1}{9}$ .

#### 7553 WAVE-FUNCTIONS AND ENERGY OF A [CONDUCTION] BAND ELECTRON IN A NaCl CRYSTAL. II.

K.B. Tolpygo and O.F. Tomasevich.

Fiz. tverdogo Tela (USSR), Vol. 2, No. 12, 3110-19 (Dec., 1960). In Russian.

The wave-functions and energies of a conduction electron in NaCl are found, taking into account exchange and correlation effects. It is found that there is an energy minimum in the centre of the zone which lies 1.58 eV below the vacuum level.  $E(k)$  is isotropic and parabolic over  $\sim 1/8$  of the volume of the Brillouin zone and the effective mass equals 0.632  $m_0$ . The ratio of the probability of finding a conduction electron on a cation and on an anion is 9.3 at  $k = 0$  and increases towards the zone boundary. A more accurate

estimate of exchange and Coulomb potentials raises the bottom of the conduction band to 2.79 eV above the vacuum level. This is in better agreement with the experimental data. M.G.Priestley

7554 ON THE FERMI SURFACE SHAPES OF THE NOBLE METALS BY ULTRASONICS.

R.W.Morse, A.Myers and C.T.Walker.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 699-700 (May, 1961).

Some revised conclusions are given: (a) The relative amount of zone boundary touching in copper and gold is nearly the same. (b) There is evidence that the main bodies of the surfaces are considerably more distorted than previously believed, being bulged outward along [100] and possibly being concave in the [110] direction.

7555 SUBSURFACE STATES IN ONE-DIMENSIONAL CRYSTALS. P.Phariseau.

Physica (Netherlands), Vol. 26, No. 12, 1192-200 (Dec., 1960).

By means of a Green's function method the energy-spectrum of an electron in a one-dimensional lattice containing only one type of atom is discussed, represented as a Dirac  $\delta$ -function. Limiting the infinite crystal model at one side, not only a potential step at the surface is obtained but also it is assumed that the first atoms are displaced. The localization of the surface states is found to depend not only on the potential strengths, the lattice constant and the height of the potential barrier at the surface, but also on the different displacements of the  $n$  atoms, i.e. on the penetration of the surface potential into the crystal. In the case that the surface potential acts only up to the second crystal cell, the existence of true surface states or Tamm-levels and of "subsurface" states is proved.

7556 TAKING INTO ACCOUNT THE INTERACTION BETWEEN CURRENT CARRIERS AND AN IONIC CRYSTAL IN TERMS OF THE MULTI-ELECTRON THEORY OF IONIC CRYSTALS. M.Sh.Gitterman.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 5, 930-2 (1958). In Russian.

Uses the model of a previous paper (Abstr. 3457 of 1958) to investigate the energy spectrum of the weakly excited electronic states in an ionic crystal assuming a strong interaction between the electrons and the ionic lattice. The interaction is that usually considered in the polaron theory for excess carriers. However, correlations are still neglected. The conclusions of the previous paper, where the interaction had not been considered, are not substantially modified. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 5, 153-5 (1958)]. L.Pincherle

7557 CALCULATING THE CORRELATION IN A SYSTEM OF PARTICLES USING GREEN'S DOUBLE-PARTICLE FUNCTION. L.Ya.Kobelev.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 4, 750-3 (1958). In Russian.

Schwinger's dynamical principle is used to construct a chain of equations for the Green's functions of an electron gas. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 4, 165-8 (1958)]. J.Goldstone

7558 THE THEORY OF THE STARK EFFECT OF EXCITONS IN IONIC CRYSTALS.

A.N.Petrov, G.G.Taluts and M.Sh. Gitterman.

Fiz. Metallov i Metallovedenie (USSR), Vol. 9, No. 3, 327-31 (1960). In Russian.

The shift of the energy level due to an external electric field is considered including the effect of electron-electron and electron-phonon interactions. The latter lead to a reduction in the order of the Stark effect. K.G.Major

7559 FINE STRUCTURE AND MAGNETO-OPTIC EFFECTS IN THE EXCITON SPECTRUM OF CADMIUM SULFIDE.

J.J.Hopfield and D.G.Thomas.

Phys. Rev. (USA), Vol. 122, No. 1, 35-52 (April 1, 1961).

The valence band of CdS is split by spin-orbit and crystal field effects into three nearly degenerate bands at  $\vec{k} = 0$ . The magneto-optic absorption spectrum of direct excitons formed from the top valence band and the conduction band was studied in detail. Most of the experiments reported were performed in light polarized parallel to the hexagonal axis. In this geometry, the exciton series consists of weak lines amenable to magneto-optic experiments. When the magnetic field and the wave vector of the light are perpendicular to each other and to the hexagonal axis, the reversal of the magnetic field produces large changes in the absorption spectrum. This effect can be quantitatively understood as an interference effect between

allowed exciton transitions (optical matrix elements independent of the wave vector of the light) and forbidden exciton transitions (optical matrix elements proportional to the wave vector of the light). It is shown that in CdS the forbidden processes having a principal quantum number 2 are somewhat stronger than allowed processes of the same quantum number. By using group theory and the effective-mass approximation, the electron and hole anisotropic  $g$  values and masses are determined from an analysis of the exciton spectrum. The electron mass,  $0.20 m_0$  (almost isotropic), determined in this analysis is compatible with the assumption that the  $\vec{k} = 0$  conduction band valley is the lowest conduction band valley. The hole masses for the top valence band are  $m_{h1} = 0.7 m_0$  and  $m_{h2} \approx 5 m_0$ . An experimental upper limit on the slope of the conduction band at  $\vec{k} = 0$  is obtained.

7560 SINGLE-PARTICLE EXCITATIONS OF A DEGENERATE ELECTRON GAS. A.J.Glick and R.A.Ferrell.

Ann. Phys. (USA), Vol. 11, No. 3, 359-76 (Nov., 1960).

The continuum of single-electron excitations determines the properties of the degenerate electron gas and, hence, also many properties of metals. In this paper Lindhard's frequency and wave-number dependent dielectric constant for the electron gas is re-derived by considering only these excitations. Collective screening and thus plasma effects, are then automatically taken into account by means of the Kramers-Kronig relations which the dielectric constant satisfies. Experiments on inelastic scattering by metal films have revealed the collective plasma excitation but have not given much information about the actual band structure and single-electron excitations in a metal. Study of the plasmon can at best only give some of the moments of the single-particle spectrum. Using the dielectric theory as a guide, an experiment is here suggested to gain information about the continuum directly. The most favourable scattering angle for studying the single-particle excitations is found to be just beyond the plasmon cutoff.

7561 A CLASSICAL INTERACTION BETWEEN THE LATTICE VIBRATIONS AND THE COLLECTIVE OSCILLATIONS OF THE ELECTRON GAS IN CRYSTALS.

B.Vasvári.

Acta Phys. chem. Szeged. (Hungary), Vol. 3, No. 1-4, 35-41 (1957). In German.

Investigates the conditions under which the lattice vibrations can give rise to plasma oscillations. L.Pincherle

7562 FLUCTUATIONS OF THE SPIN DENSITY IN THE ELECTRON PLASMA. V.M.Yeleonski and P.S.Zyrya.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 3, 573-5 (1958). In Russian.

The authors calculate the dispersion equation for spin fluctuations due to spin-spin and spin-orbit interactions. No quantitative account is taken of correlation or Coulomb exchange effects. It is concluded that spin fluctuations have a negligible effect on the physical properties of metals. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 3, 187-9 (1958)]. M.G.Priestley

7563 THE INITIAL PROBLEM FOR A LONGITUDINAL FIELD IN A DEGENERATE ELECTRON GAS. V.P.Silin.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 6, 942-3 (Dec. 1960). In Russian.

7564 MAGNETOPLASMA EFFECTS IN SOLIDS.

B.Lax.

IRE Trans Microwave Theory and Tech. (USA), Vol. MTT-9, No. 1, 83-9 (Jan., 1961).

Plasmas in solids show a more complex behaviour than in gases since they reflect the symmetry properties of crystals. Since the carrier concentration has a wide range in semiconductors and metals, the plasma phenomena can be studied from microwaves to the ultraviolet. The effect of magnetic fields on the electromagnetic properties of plasmas has been experimentally investigated at microwave and infrared frequencies and has been utilized to measure dielectric constant and band structure of such solids in the limit of low magnetic fields. The magnetoplasma exhibits effects analogous to the galvanomagnetic phenomena. However, near resonance in the classical limit, they show up as depolarizing effects in semiconductors and also give rise to a new type of cyclotron resonance under anomalous skin conditions in metals.

# 7565 COHERENT EXCITATION OF PLASMA OSCILLATIONS IN SOLIDS. D.Pines.

IRE Trans Microwave Theory and Tech. (USA), Vol. MTT-9, No. 1, 39-92 (Jan., 1961).

Considerations are put forth concerning the feasibility of observing the coherent excitation of plasma oscillations in a two-component plasma of electrons and holes in semiconductors or semimetals. By coherent excitation is meant the onset of a high-frequency ("two-stream") instability arising from an appreciable drift of electrons versus holes under the action of an applied electric field. Conditions favourable to coherent excitation include a sizeable difference in electron and hole masses, and long relaxation times for both kinds of particles. The extent to which such conditions are present in InSb is discussed.

# 7566 ON THE STABILITY OF AN ELECTRON GAS AT LOW DENSITY. M.Shimizu.

J. Phys. Soc. Japan, Vol. 15, No. 2, 217-19 (Feb., 1960).

Discussion on the basis of the energy spectrum of a quasi-particle given by the Bohm-Pines theory.

# 7567 A VARIATIONAL APPROACH TO CORRELATION IN AN ELECTRON GAS. W.H.Young.

Phil. Mag. (GB), Vol. 6, 371-7 (March, 1961).

A method is proposed for calculating correlation energies and pair functions associated with an electron gas at any density. Upper bounds to the exact energy, lying however at least as low as the corresponding plane wave results, are guaranteed and exact solutions are obtained in the high- and low-density limits. The technique used is that of allowing a periodic electron density and a proof emerges of the recent conjecture of Overhauser (Abstr. 1810, 11125, 13513 of 1960) that there exist one-particle states energetically more favourable than the usual plane wave orbitals. It is concluded that in the ground state a single-particle approximation implies static spin density waves of wavelength proportional to the usual separation electron parameter  $r_s$ , at least for  $r_s$  sufficiently large.

# 7568 EXPERIMENTAL VERIFICATION OF RADIATION OF PLASMA OSCILLATIONS IN THIN SILVER FILMS.

W.Steinmann.

Phys. Rev. Letters (USA), Vol. 5, No. 10, 470-2 (Nov. 15, 1960).

## PLASMON RERADIATION FROM SILVER FILMS.

R.W.Brown, P.Wessel and E.P.Trounson. Ibid., 472-3.

Two letters reporting observation of light emitted at the plasma frequency, as predicted by Ferrell (Abstr. 1858 of 1959), in films bombarded by 22-25 kV electrons. A peak is found in the radiated spectrum at  $\sim 3300$  Å, with a sharp cut-off at shorter wavelengths. Steinmann shows that the intensity fluctuates with film thickness in the predicted way, and that the electron energy loss spectrum shows a peak at the same energy. Brown et al. show that the radiated spectrum varies with observing angle in the predicted way.

R.G.Chambers

# HIGHER RANDOM-PHASE APPROXIMATION FOR AN ELECTRON GAS. See Abstr. 6801

## ANNIHILATION OF POSITRONS IN LiH.

7569 A.T.Stewart and R.H.March.

Phys. Rev. (USA), Vol. 122, No. 1, 75-6 (April 1, 1961).

The angular correlation of photons from positron annihilation in LiH and NaH was measured. The data yield a wave-function product density distribution much wider than the outer-shell electron density around the negative ion. This result is in contrast with the observations for other alkali halides, for which these two distributions are much alike.

# 7570 CYCLOTRON RESONANCE IN INDIUM ANTIMONIDE AT HIGH MAGNETIC FIELDS.

B.Lax, J.G.Mavroides, H.J.Zeiger and R.J.Keyes.

Phys. Rev. (USA), Vol. 122, No. 1, 31-5 (April 1, 1961).

The room temperature, pulsed magnetic field infrared cyclotron resonance data of Keyes et al. (Abstr. 2211, 2229 of 1957) in InSb is interpreted using the  $k \cdot p$  perturbation technique of Kane [J. Phys. Chem. Solids (GB), Vol. 1, 249 (1957)], which is extended to include the effects of a d.c. magnetic field. The energy levels are calculated for a carrier in a band in the presence of a magnetic field and which is interacting with neighbouring bands. From the energy expression the variation of the apparent effective mass with magnetic field is calculated. The theory is consistent with the room temperature measurements of Keyes et al., as well as with other cyclotron resonance results obtained at low temperatures.

## CYCLOTRON RESONANCE IN GERMANIUM.

7571 R.R.Goodman.

Phys. Rev. (USA), Vol. 122, No. 2, 397-405 (April 15, 1961).

Early cyclotron resonance for holes in Ge gave evidence of two resonant peaks associated with the so-called light and heavy holes. Luttinger and Kohn predicted (Abstr. 3742 of 1955), on the basis of a careful investigation of the theory of degenerate bands, that at low enough temperatures additional peaks should appear. Subsequent experiments confirmed this prediction. In this paper a comparison is made of the cyclotron resonance theory and the experiments of Fletcher et al. (Abstr. 330 of 1956). Values of the effective mass constants which best fit the data are found. Resonant peaks additional to those found by Fletcher et al. are predicted and discussed.

## INFRARED CYCLOTRON RESONANCE IN InSb.

7572 E.D.Palik, G.S.Picus, S.Teitler and R.F.Wallis.

Phys. Rev. (USA), Vol. 122, No. 2, 475-81 (April 15, 1961).

Far-infrared cyclotron resonance absorption in n-type InSb was measured to determine the variation of the conduction electron effective mass with magnetic field. At high magnetic fields the absorption was resolved into a strong line with a weaker satellite line at lower photon energy and a broad, weak absorption at still lower energy. The interpretation of this structure in terms of the conduction-band properties of InSb is discussed.

## INTERACTION OF SLOW ELECTRONS WITH

## INSULATING CRYSTALS. I. ABSORPTION COEFFICIENT FOR CLEAVED ALKALI HALIDES; EXPERIMENTAL TECHNIQUES.

C.J.Cook and W.J.Fredericks.

J. appl. Phys. (USA), Vol. 32, No. 5, 860-6 (May, 1961).

Techniques were developed that permit a unique determination of an absorption coefficient  $\alpha_0$  for 0.2 to 20 eV electrons on cleaved, insulating crystals. Two classes of electron trapping levels, one that empties rapidly and one that does not empty at room temperature, may exist in the target and if they do, effects caused by them may perturb the data. Experimental techniques were developed to compensate for each characteristic effect. Pure and nonstoichiometric KBr and KCl crystals were studied. The probability that a crystal-incident electron results in a charge influx was found to vary markedly as a function of the impact energy and in a manner characteristic of the target. This feasibility study indicates that slow electron beams could be a powerful tool for diagnosing surface and bulk properties of insulating crystals.

## TRANSMISSION OF SLOW ELECTRONS THROUGH THIN FILMS.

See Abstr. 7102

## DEFECT PROPERTIES

## 7574 THE REAL STRUCTURE OF CADMIUM SULPHIDE CRYSTALS. H.Radel.

Wiss. Z. Humboldt-Univ. Berlin, math.-nat. Reihe (Germany), Vol. 9, No. 3, 365-75 (1959-60). In German.

The various kinds of gross defects which are found in CdS crystals are described. The crystals have the wurtzite structure space group  $C_{6v}^4$  and the orientation of the unit cell axes to the axes of the macroscopic crystals depends on the conditions of growth. The defects in the structure were studied by optical microscopic methods, by X-ray diffraction and other techniques. The observations of defects on both the macro- and micro-scale are related to the process of crystal growth. The effects of these defects on the physical properties of actual crystals were investigated and the results are reported. A detailed investigation of the lamellar structure of individual crystals confirms the ideas put forward by Graf [Z. Phys. (Germany), Vol. 121, 73 (1943)] on lamellar crystal growth.

J.Iball

## DETERMINATION OF THE ENERGY OF FORMATION

## OF VACANCIES AND OF THEIR NUMBER IN PURE

7575 S.D.Gertsriken and B.F.Slyusar.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1061-9 (1958). In Russian.

The formation energies  $E_d$  for gold, copper, silver, aluminium, zinc, lead, cadmium and tin were determined by electrical resistance measurements over a wide temperature range, and also by a dilatometric method in the case of aluminium, zinc, lead, tin and cadmium. The values for  $E_d$  obtained by the two methods agree satisfactorily with the experimental and theoretical results available

for some of these metals. It has been shown that for certain metals  $E_d/E_{sd} = 1/3$ , where  $E_{sd}$  is the activation energy of self-diffusion. For the metals under investigation, a calculation is made of the pre-exponential multiplier  $x$  in Frenkel's equation  $n/N = x \exp(-E_d/RT)$ , where  $n$  is the number of vacancies at temperature  $T$ ,  $N$  the number of atoms in the crystal. The appropriate number of vacancies near the melting point and the specific resistance per 1 percent of vacancies are worked out. [English translation in: Phys. Metals and Metallography 103-11 (1958)].

#### 7576 DETECTION AND DETERMINATION OF EQUILIBRIUM VACANCY CONCENTRATIONS IN ALUMINUM.

S.Nenno and J.W.Kauffman.

J. Phys. Soc. Japan, Vol. 15, No. 2, 220-6 (Feb., 1960).

In order to obtain direct information concerning the equilibrium vacancy concentrations and the energy of formation of a vacancy in Al, a method of combining the bulk and lattice thermal expansion measurements was used. In the present work, only the lattice thermal expansion measurements on 99.996% pure Al were made. The data obtained were analysed using bulk thermal expansion data on Al (of the same purity) available in the literature. The concentration of vacancies increases exponentially with temperature and its value at the melting point is  $(1.1 \pm 0.2) \times 10^{-3}$  and the energy of formation of a vacancy is estimated to be  $(0.64 \pm 0.12)$  eV.

#### 7577 CALORIMETRIC DETERMINATION OF THE FORMATION ENERGY OF VACANCIES IN GOLD.

V.A.Pervakov and V.I.Khotkevich.

Dokl. Akad. Nauk SSSR, Vol. 134, No. 6, 1328-30 (Oct. 21, 1960). In Russian.

For abstract, see Abstr. 3654 of 1961. [English translation in: Soviet Physics - Doklady (USA), Vol. 5, No. 5, 1051-3 (March-April, 1961)].

#### 7578 INTERSTITIAL VERSUS SUBSTITUTIONAL OXYGEN IN SILICON. W.L.Bond and W.Kaiser.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 44-5 (Nov., 1960).

Lattice constant and density studies on oxygen-free and oxygen-doped silicon single crystals suggest that oxygen occupies an interstitial lattice site.

#### 7579 DECOMPOSITION OF DISLOCATIONS IN IRON AND THE BODY CENTRED CUBIC METALS. C.Crussard.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 273-6 (Jan. 9, 1961). In French.

This note is a theoretical study of the crystallographic conditions that ought to exist at a stacking fault on a  $\{112\}$  plane in the body centred cubic lattice. The importance of the Suzuki effect in such a lattice is emphasized and the author concludes that by such considerations it is possible to explain many of the mechanical properties of iron.

R.Bullough

#### CIRCULAR EDGE DISLOCATION LOOP.

7580 F.Kroupa.

Czech. J. Phys., Vol. 10, No. 4, 284-93 (1960).

A solution of the stress, deformation and deformation energy is given for an edge dislocation with its dislocation line having the shape of a circle in an unlimited isotropic medium. The possibility of using this solution in studying the dislocation loop in a crystal is discussed.

#### 7581 A POSSIBLE MECHANISM OF FORMATION OF SLIP-LINES IN THE ABSENCE OF LOCALIZED SOURCES OF DISLOCATIONS. E.D.Shchukin.

Dokl. Akad. Nauk SSSR, Vol. 135, No. 1, 61-4 (Nov. 1, 1960). In Russian.

A mechanism related to that of Amelinckx and Dekeyser (Abstr. 7507 of 1958) is proposed for the multiplication of dislocation lines to form a slip band, without Frank-Read sources. A short length of one growing dislocation loop undergoes cross-slip into a parallel slip-plane, where it forms an independent loop. If this is a random event, in either direction, resulting from internal stresses and intersecting dislocations, the slip band will have a thickness proportional to the square root of its total slip. [English translation in: Soviet Physics - Doklady (USA)].

I.D.C.Gurney

#### 7582 LORENTZ FORCE ON SCREW DISLOCATIONS AND RELATED PROBLEMS. J.Lothe.

Phys. Rev. (USA), Vol. 122, No. 1, 78-82 (April. 1, 1960).

The concept of a Lorentz force on screw dislocations, first introduced by Nabarro (Abstr. 9344 of 1951) is analysed. It is concluded that the Nabarro-Lorentz force on screws and the Lorentz force of electromagnetism are not analogous, and that the term a

Lorentz force on screws should be dropped in order to avoid confusion. Only when the screw is constrained to move on one slip plane is the analogy with electromagnetism complete. Total quasi-momentum is not generally conserved when screw dislocations interact with elastic waves.

#### ABRUPT-KINK MODEL OF DISLOCATION MOTION.

7583 A.D.Brailsford.

Phys. Rev. (USA), Vol. 122, No. 3, 778-86 (May 1, 1961).

A new model of dislocation motion is presented. The behaviour of a dislocation in the presence of an applied stress is described in terms of a redistribution of kinks along its length. In contrast with previous models, in which a kink is envisaged as a smooth step extending over many lattice constants, a kink is supposed to be abrupt. Consequently, kink diffusion is considered to be a thermally activated process. Transport equations are formulated which include the effects of generation, diffusion, and collision of kinks. General results obtained from these equations show that a dislocation does not behave like an extensible string in this model. Particular application to small harmonically-time-dependent stresses leads naturally to a new theory of the Bordoni anelastic peak. The characteristic relaxation time depends on line length as well as the attempt frequency and activation energy for diffusion. As a result the decrease in the peak height and slight lowering of the peak temperature upon alloying or neutron irradiation are explained. Assuming an exponential distribution of line lengths, the results of the theory are used to evaluate the merit of different published values of the activation energy. Calculated attenuation peaks for different frequencies are shown to account for the experimentally observed large half-widths in pure cold-worked metals. The absence of a peak in well-annealed metals is explained if dislocations are then arranged parallel to the close-packed directions, thereby eliminating the kink density. The process by which cold-working annealed materials can give rise to kinks is discussed. Experiments are suggested which might further test the theory.

#### DISLOCATION INTERACTION IN B.C.C. STAINLESS STEEL.

7584

B.R.Banerjee, J.M.Capenos, J.J.Hauser and J.P.Hirth. J. appl. Phys. (USA), Vol. 32, No. 3, 556-7 (March, 1961).

Several dislocation distributions were observed by transmission electron microscopy in tempered stainless steel containing 11.94% Cr and 0.11% C.

R.F.Pearl

#### INTERACTION BETWEEN VACANCIES AND STACKING FAULT RIBBONS IN GRAPHITE.

7585

P.Delavignette and S.Amelinckx. J. appl. Phys. (USA), Vol. 32, No. 3, 554-5 (March, 1961).

A precipitation process is described which it is suggested contributes to the quench hardening and radiation hardening of graphite.

R.F.Pearl

#### STACKING FAULT PROBABILITY OF NOBLE

7586 METAL-ZINC ALLOYS. L.F.Vassamillet.

J. appl. Phys. (USA), Vol. 32, No. 5, 778-82 (May, 1961).

The stacking fault probability was measured by X-ray means on a number of alloys of gold, silver, and copper with varying zinc content. By using these probabilities, the relative magnitudes of the stacking fault energies were deduced.

#### SPECTROSCOPY OF TRAPPING CENTRES IN

7587 INSULATORS BY MEANS OF MAJORITY CARRIER INJECTION. W.Ruppel.

Abhandl. Deutschen Akad. Wiss. Berlin, Kl. Math. Phys. Tech. (Germany), 1960, No. 7, p. 147-54. In German.

"Electron processes in solids" conference (see Abstr. 2382 of 1961). Suggests that under certain conditions the concentrations of various types of trapping centres and the position of the Fermi level in insulators may be determined from studies of the space-charged limited current.

L.Pincher

# Diffusion

## 7588 ON DIFFUSION IN VOLUME AND ALONG GRAIN BOUNDARIES.

B.S.Bokshtein, I.A.Magidson and I.L.Svetlov.  
Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1040-52 (1958).  
In Russian.

Earlier theoretical work is discussed and then a new model based on spherical grains is treated. Solutions are presented which, from the assumptions made, are applicable to small grains and long diffusion times. Experimental data obtained by other workers are treated and the results are compared with those obtained from using the solutions based on other models. It is suggested that the model could also be applied to the evaluation of diffusion processes in powders and eutectics. [English translation in Phys. Metals and Metallography (GB), Vol. 6, No. 6, 81-95 (1958)]. A.E.Kay

## 7589 STATISTICAL DYNAMICS OF CRYSTALLINE DIFFUSION. I. EXCHANGE MECHANISM. R.Kikuchi.

Ann. Phys. (USA), Vol. 11, No. 3, 306-27 (Nov., 1960).  
The path probability method for irreversible cooperative phenomena proposed by the author is applied to atomic diffusion in crystals. A binary alloy of body-centred cubic structure with the concentration gradient along a [100] direction is discussed, with the direct exchange mechanism for atomic migration assumed. The path probability  $G$  for change of state during a short time interval is written in terms of the path parameters  $\{Y_{ij}\}$  using the pair approximation of the cluster-variation method. The most probable path is determined by maximizing  $G$  with respect to  $\{Y_{ij}\}$ . The system is isothermal and a flow of atoms is maintained by two particle reservoirs of different chemical potentials placed at the two ends of the system. When there is no chemical potential gradient, the system is an equilibrium state identical to that obtained by the pair approximation, which is equivalent to Bethe's approximation or the quasi-chemical approximation. The diffusion coefficient is obtained from the stationary state by expanding the state parameters in terms of the concentration gradient. The expression of the diffusion coefficient is given for an arbitrary value of the concentration, and is written in terms of a probability parameter for a unit interchange of atoms.

## 7590 SOME FEATURES OF SELF-DIFFUSION IN METALS. S.D.Gertsriken.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 6, 873-8 (Dec., 1960). In Russian.

The volume self-diffusion coefficients, extrapolated to the melting point, are shown to be approximately the same for all elements in one subgroup of the periodic system. The self-diffusion coefficients in the interior of a crystal grain and along its boundaries should be roughly the same in the solid phase near the melting point, provided the grain boundaries are several microns thick. A.Tybulewicz

## 7591 THE COEFFICIENTS OF SELF-DIFFUSION IN ALLOYS. B.Ya.Pines and I.V.Smushkov.

Fiz. tverdogo Tela (USSR), Vol. 3, No. 1, 146-53 (Jan., 1961).  
In Russian.

Reports calculations of the diffusion coefficients of the alloy components and the self-diffusion coefficient of "average" atoms of the alloy as a function of composition. [English translation in: Soviet Physics—Solid State (USA)]. A.Tybulewicz

## 7592 DIFFUSION OF ARSENIC IN GERMANIUM FROM THE VAPOUR PHASE. W.Albers.

Solid-State Electronics (GB), Vol. 2, No. 2-3, 85-95 (March, 1961).

The diffusion of arsenic in germanium was measured. The diffusion constants and the concentration of As at the surface in equilibrium with gaseous arsenic of a certain pressure were determined at different temperatures. From the temperature dependence, the activation energy of diffusion and the pre-exponential constant are calculated. It is found that, if the diffusion is carried out via the vapour phase and if the diffusion vessel contains zones of different temperatures, the surface concentration of the arsenic depends on the geometry of the vessel, when working in the absence of an inert gas. This effect is caused by the fact that the degree of dissociation of the gaseous As molecules above the germanium sample depends on the geometry of the vessel. A method for the eradication of thermal conversion is described.

## DIFFUSION OF BERYLLIUM IN GERMANIUM.

7593 Yu.I.Belyaev and V.A.Zhidkov.

Fiz. tverdogo Tela (USSR), Vol. 3, No. 1, 182-4 (Jan., 1961).  
In Russian.

Reports a determination of the diffusion coefficient  $D$  and the solubility  $c_0$  of Be in monocrystalline Ge at 720-920°C. Both  $D = 0.5 \exp(-2.5/kT)$  and  $c_0 \sim 10^{16} \text{ cm}^{-3}$  were not greatly affected by temperature in this range. [English translation in: Soviet Physics—Solid State (USA)]. A.Tybulewicz

## 7594 HETERODIFFUSION OF CHLORINE AND IODINE IONS IN SOME ALKALI-HALIDE SINGLE CRYSTALS.

J.C.Beaumont and J.Cabané.

C.R.Acad. Sci. (France), Vol. 252, No. 1, 113-15 (Jan. 4, 1961). In French.

Describes the results obtained for the diffusion of  $\text{Cl}^-$  in KI, and for  $\text{I}^-$  in KCl and in NaCl. In each case the activation energy is the same as that for the diffusion of the lattice anions of the given crystal. See also following abstract. D.G.Holloway

## 7595 HETERODIFFUSION OF CHLORINE AND IODINE IN SOME ALKALI HALIDE POLYCRYSTALS.

J.C.Beaumont and J.Cabané.

C.R.Acad. Sci. (France), Vol. 252, No. 2, 266-8 (Jan. 9, 1961). In French.

The diffusion coefficient of  $\text{Cl}^-$  was greater in polycrystalline KI than in the single crystal. For the diffusion of  $\text{I}^-$  in polycrystalline KCl and NaCl, grain boundary diffusion was much faster and was detected directly by autoradiography. See also preceding abstract. D.G.Holloway

## 7596 MOBILITY OF CHROMIUM ATOMS IN A NICKEL—CHROMIUM ALLOY UNDER THE INFLUENCE OF A CONSTANT ELECTRIC FIELD.

D.F.Kalinovich, I.I.Kovenski, M.D.Smolin and I.N.Frantsevich.  
Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 42-6 (July, 1960). In Russian.

Electrical migration of Cr in a 4.36% Cr—Ni alloy at 950-1100°C was studied by the radioactive tracer method. There was a definite movement of the Cr atoms towards the cathodic end of the specimen, the rate of transfer in the surface layer being four times higher than that in the interior of the wire. With the aid of the Einstein formula, the effective charge of Cr ions at various temperatures is calculated. M.H.Sloboda

## THE DIFFUSION OF HYDROGEN IN SINGLE-CRYSTAL GERMANIUM. R.C.Frank and J.E.Thomas, Jr.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 144-51 (Nov., 1960).

Single-crystal germanium diffusion specimens were prepared by a special process of drilling and crystal growing. The hollow cylindrical specimen was sealed at one end and attached to a mass spectrometer at the other. By surrounding the thin cylinder with hydrogen gas and observing it diffuse through into the mass spectrometer permeation rates and diffusion coefficients were measured in the temperature range of 800 to 910°C. The excellent agreement between diffusion coefficients measured by the "time lag" and decay curve methods indicates that trapping effects by lattice defects were small or non-existent. The activation energy for diffusion is  $8.7 \pm 0.8 \text{ kcal/g atom}$  and the heat of solution is  $52.8 \pm 1.4 \text{ kcal/g atom}$ . The permeation rate was found to vary as the square root of the gas pressure, which indicates that the hydrogen exists in the germanium lattice as hydrogen atoms or ions.

## 7598 SELF-DIFFUSION IN SILVER DURING PLASTIC DEFORMATION IN TORSION.

J.B.Darby, Jr, C.T.Tomizuka and R.W.Balluffi.

J. appl. Phys. (USA), Vol. 32, No. 5, 840-8 (May, 1961).

Self-diffusion of  $\text{Ag}^{110}$  in silver polycrystals subjected to simultaneous torsion was studied near 700° and 800°C using the sectioning technique. Strains  $\leq 0.50$  and strain rates  $\leq 13.8 \times 10^{-5} \text{ sec}^{-1}$  were employed. Specimen structures before and after deformation were also examined. The effects of straining on diffusion were relatively small in all cases. At 800°C the diffusivity was increased by no more than ~50%. At 700°C the increase was no more than ~100%. A substantial part of this observed enhancement was undoubtedly only apparent and due to difficulties associated with surface roughness. The results agreed generally with previous work involving deformation in extension and compression but were in marked disagreement with recent results of Lee and Maddin and Forestieri and Girifalco [Transactions of the American Institute of Mechanical Engineers, Vol. 215, 397 (1959) and Abstr. 2828 of 1960], who have reported enhancements larger by one to two orders of magnitude.

No simple explanation for these differences was found. Estimates of dislocation short-circuiting and the generation of extra point defects indicated that only small enhancements should be expected in agreement with the present results.

#### 7599 EXPERIMENTAL STUDY OF INTERMETALLIC DIFFUSION IN LARGE TEMPERATURE GRADIENTS.

C.J.Meechan.

J. appl. Phys. (USA), Vol. 32, No. 5, 945-50 (May, 1961).

Temperature gradients in the range 2000-3000°C/cm were imposed across the interface of binary diffusion couples fabricated from f.c.c. metals. The systems investigated were Au-Ni, Cu-Ni,  $\gamma$ Fe-Ni,  $\gamma$ Fe-Pd, and Ni-Pd. It was found that chemical diffusion in these systems was influenced in varying degrees by the temperature gradient. Suggestions are made for the manner in which the temperature gradient may affect the various contributions to chemical diffusion.

## Colour Centres

#### 7600 DICHROIC COLOR CENTERS IN CALCIUM FLUOROPHOSPHATE. P.D.Johnson.

J. appl. Phys. (USA), Vol. 32, No. 1, 127-8 (Jan., 1961).

Single crystals of calcium fluorophosphate prepared synthetically were found to be visibly dichroic. The close agreement of experimental and calculated transmission data for a uniaxial absorber in a spectral region of strong absorption indicates that the absorbing centre is uniaxial and orientated parallel to the crystal c-axis of the hexagonal crystal. From a consideration of the crystal geometry and the features of the energy absorption it is concluded the absorbing centres are probably at or between fluoride sites, three possibilities being O<sup>-</sup> substituted for F<sup>-</sup>, an F centre, or a V centre.

J.W.Taylor

#### 7601 PHOTOCHEMICALLY PRODUCED COLOR CENTERS IN KCl AND KBr. J.A.Cape.

Phys. Rev. (USA), Vol. 122, No. 1, 18-25 (April 1, 1961).

KCl and KBr crystals were exposed to unfiltered mercury arc radiation at 15°K. If an "OH" band was present in the crystals before irradiation, the ultraviolet irradiation produced an optical absorption spectrum similar to that produced by X-rays at 15°K. The optical absorption spectrum and the changes in the absorption produced by annealing at higher temperatures were measured and compared with the spectra observed during similar annealing of X-irradiated crystals. In KCl the 335 m $\mu$  band, formed by the u.v. irradiation, bleaches thermally at 56°K as does the 335 m $\mu$  H band of X-irradiated KCl. In KBr the 381 m $\mu$  band bleaches in steps at 35°, 46°, 56° and 80°K as compared with the 381 m $\mu$  H band in X-irradiated KBr which bleached at 30°, 46°, 56° and 80°K. In both KCl and KBr the V<sub>1</sub> band appears with the disappearance of the H band. Illumination in the V<sub>1</sub> band causes regeneration of the H band as occurs in X-irradiated KCl and KBr. In both KCl and KBr the photoproduced H band grows by about 10% at approximately 25°K. It is concluded that the H centres bleach thermally by diffusing to and combining with other color centres. Recombination with F and  $\alpha$  centres annihilates the H centres and leads to the formation of H<sub>k</sub> centres, while recombination with a third centre (possibly a positive-ion vacancy) results in the formation of V<sub>1</sub> centres. U, U<sub>1</sub>, U<sub>2</sub>, O<sup>-</sup>, and  $\alpha$  centres are produced by the u.v. irradiation as well as F and H centres. The photoproduced F band may be bleached optically with negligible effect on the H band.

#### 7602 PHOTOCHEMISTRY OF THE V<sub>1</sub> CENTER.

J.D.Kingsley.

Phys. Rev. (USA), Vol. 122, No. 3, 772-8 (May 1, 1961).

A series of photochemical experiments on the colour centres present in KBr and KCl after exposure to X-rays at 80°K is discussed. These experiments are chemical in nature, the reactions being triggered through exposure to radiation of various wavelengths. It is shown that the only V centre which has a large electron capture cross-section is the V<sub>K</sub> centre, and the cross-section of the V<sub>1</sub> centre is very small. It is also shown that the destruction of the V<sub>1</sub> centre does not involve the annihilation of an electron or hole trapped at a crystal imperfection but apparently involves the addition of an interstitial to the F centre, yielding as a product the undisturbed lattice. The implications of these observations as they relate to the structure of the V<sub>1</sub> centre are discussed.

## Radiation Effects

#### IRRADIATED POLYMERS.

7603 R.M.Black and A.Charlesby.

Progress in dielectrics, Vol. 2 (see Abstr. 5413 of 1961) p. 77-111.

Detailed review of the temporary and permanent effects of ionizing radiation on polymers. The subjects covered include sources of high-energy radiation; mechanism of interaction of radiations; temporary effects and semiconductor-like behaviour; permanent effects, including cross-linking, degradation, gas evolution, effects of temperature and oxygen, and changes in electrical properties; recent developments in the radiation chemistry of polymers; and practical applications. 94 refs.

J.B.Birk

#### 7604 FOCUSING 110 COLLISION CHAINS IN FACE-CENTRED CRYSTALS AT SMALL ANGLES.

C.Lehmann and G.Leibfried.

Z. Phys. (Germany), Vol. 162, No. 2, 203-14 (1961). In German.

Focusing collisions along  $\langle 110 \rangle$  directions in f.c.c. lattices are investigated. For small angular deviations from this direction, an exact treatment of subsequent collisions is possible. The results are compared with machine calculations by Vineyard et al. (Abstr. 20856 of 1960). The agreement is practically complete. The influence of neighbouring atomic chains can be neglected.

#### 7605 STORED ENERGY RELEASE BELOW 80°K IN DEUTERON-IRRADIATED COPPER.

A.V.Granato and T.G.Nilan.

Phys. Rev. Letters (USA), Vol. 6, No. 4, 171-3 (Feb. 15, 1961).

A differential calorimeter was used with an annealing rate of 2 deg K/min. The energy release shows peaks at 29°, 34°, and 42°K with some structure in the last of these. These are interpreted as due to interstitial-vacancy recombination mechanisms. It is deduced that there is a resistivity of 2.6 microhm cm per 1% Frenkel pairs and a volume change of 1.2 atomic volumes per Frenkel pair.

M.G.Priestley

#### 7606 FREQUENCY FACTORS FOR ANNEALING FAST-NEUTRON INDUCED DENSITY CHANGES IN VITREOUS SILICA. W.Primak, H.Szymanski and D.Keiffer.

J. appl. Phys. (USA), Vol. 32, No. 4, 660-8 (April, 1961).

Isothermal and step-annealing data were obtained, and show that the frequency factor  $\sim 10^{14}$ /sec for processes having activation energies beyond the peak of the distribution but some orders of magnitude lower and possibly dispersed for the portions of the distribution at activation energies less than the peak.

#### NEUTRON IRRADIATION OF GRAY TIN.

7607 A.N.Goland.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 46-52 (Nov., 1960).

Gray tin was irradiated at 0°C in a reactor in an effort to produce white tin as a result of localized heating caused by thermal spikes. The irradiated powder was compared to an unirradiated specimen by means of X-ray studies at low temperatures. No significant change was found in the amount of white tin present as a result of irradiation. The implications of this result for the thermal-spike concept are discussed and various explanations for the experimental results are offered.

#### 7608 ENERGY RELEASE IN REACTOR-IRRADIATED COPPER. II. 600 to 700°K RELEASE.

T.H.Blewitt, S.T.Sekula and J.Diehl.

Phys. Rev. (USA), Vol. 122, No. 1, 53-7 (April 1 1961).

For previous work see Abstr. 13805 of 1959. The energy release associated with the recovery peak occurring between 600° and 700°K in neutron-irradiated copper was measured utilizing a new technique, that of nuclear heating. Following a bombardment at 40°C of  $1.7 \times 10^{20}$  fast neutrons of a 1/E distribution which raised the critical shear stress to 12.8 kg/mm<sup>2</sup> at 4.2°K (5.2 kg/mm<sup>2</sup> at 300°K), a release of 7.7 cal/mole was measured. Using this measured value of the energy release it is possible to estimate the number of defects annihilated if it is assumed that the annealing is the result of the migration and subsequent annihilation of a single defect. In this way the number of interstitials, vacancies, interstitial-vacancy pairs, and dislocation lines required to account for the measured energy release were estimated. The values were, respectively,  $5 \times 10^{19}$  per mole,  $2 \times 10^{20}$  per mole,  $4 \times 10^{19}$  per mole, and  $1 \times 10^{12}$  cm per mole.

# 7609 ANNEALING OF $\gamma$ -RAY DAMAGE IN GERMANIUM.

T.Asada, H.Saito, K.Omura, T.Oku and M.Oka.

J. Phys. Soc. Japan, Vol. 15, No. 1, 93-4 (Jan., 1960).

Isothermal annealing of germanium single crystals irradiated with  $\text{Co}^{60}$   $\gamma$ -rays was studied. The variation of electrical conductance with time was measured. The conductance curves had three stages. To explain this fact, the model proposed by Fletcher and Brown may be employed with a certain modification. From the analysis of these curves, the activation energy of the direct recombination of vacancy-interstitial pairs, that for the diffusion of interstitial atoms and that for the diffusion of vacancies were found to be 0.765 eV, 0.741 eV, and 1.250 eV, respectively.

## ELECTRICAL PROPERTIES OF SOLIDS

(Superconductivity is included under  
Low-Temperature Physics)

# 7610 ELECTRON MICROSCOPE STUDY OF RADIATION DAMAGE IN GRAPHITE. W.Bollmann.

J. appl. Phys. (USA), Vol. 32, No. 5, 869-76 (May, 1961).

Neutron-induced defects in the graphite lattice were studied by dark-field transmission electron microscopy. The annealing was followed and the appearance of the defects interpreted on the basis of the kinematical theory of electron diffraction. A physical interpretation of the observations based on displacement spikes and their annealing is given.

# 7611 THE EFFECT OF SHORT-RANGE ORDER ON ELECTRICAL PROPERTIES OF A SUBSTANCE.

A.B.Almazov.

Fiz. tverdogo Tela (USSR), Sbornik [Supplement] II, 158-61 (1959). In Russian.

General expressions for the potential energy of electrons in a substance with short-range order are derived. They can be used to deal with crystals under shear stress, crystals with defects and impurities, macroscopically uniform and isotropic substances, effects of ideal and non-ideal surfaces, thermo-e.m.f.'s, lattice vibrations in an ideal crystal, etc.

A.Tybulewicz

# 7612 THE ANOMALY IN THE ELECTRICAL RESISTANCE OF THE ALLOY Ni<sub>3</sub>Cr. N.V.Semenova.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1017-26 (1956). In Russian. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 57-66 (1958)].

# 7613 INFLUENCE OF THE PRESSURE OF A NEUTRAL GAS ON THE RESISTANCE OF A NICKEL WIRE.

G.Volovick.

C.R. Acad. Sci. (France), Vol. 252, No. 9, 1285-7 (Feb. 27, 1961). In French.

A nickel wire was studied over the temperature range 0 to 40°C and in ambient atmospheres of nitrogen at pressures ranging from 195 to 1050 kg/cm<sup>2</sup>. At a given temperature the resistance increases slowly for a pressure increase from 195 to 550 kg/cm<sup>2</sup> and then more rapidly up to 1050 kg/cm<sup>2</sup>. The form of variation is similar at each temperature studied.

C.A.Hogarth

# 7614 ON THE CAUSES OF AND MEANS OF REDUCING THE INSTABILITY OF HIGH PRECISION RESISTANCE

ALLOYS. V.S.Mes'kin and E.A.Al'tan.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 90-100 (July, 1960). In Russian.

The effect of various factors on the stability of electrical resistivity,  $\rho$ , of the 83 Cu/12.4 Mn/2.5 Ni/1.1 Co alloy was investigated. It is concluded that the variation of  $\rho$  of wire specimens of this and other similar alloys is caused by gradual evolution of dissolved H and by the formation of a surface oxide layer. The following means of improving the performance of the alloy studied are suggested: reducing the H content in the alloy by strict control of the melting and pickling operations; removal of dissolved H by (a) annealing at ~580°C in a neutral atmosphere, or (b) low temperature treatment in an ultrasonically agitated oil bath; ultrasonic treatment of the wire combined with passage of high density electric current; preventing oxidation in service by using a reducing or neutral atmosphere.

M.H.Sloboda

# 7615 THE ELECTRICAL RESISTANCE OF PURE Au AND Ag AT LOW TEMPERATURES.

B.Knook and G.J.van den Berg.

Physica (Netherlands), Vol. 26, No. 7, 505-12 (July, 1960).

For measurements on the electrical properties of a dilute alloy of a noble metal and a transition element the purity of the metals is of great importance. The preparation of the samples can give rise to difficulties caused by unwanted contamination. It was found that rolled strips of pure Au and Ag gave lower values for the residual resistance than drawn wires. The residual resistance can be regarded as a good measure of the purity, perhaps even better than the temperature coefficient between 0°C and 100°C. It was therefore concluded that the preparation of strips may introduce less contamination than that of wires, a conclusion which is confirmed by the disappearance of the minimum of the resistance in some cases. This is important for measurements on dilute alloys, because unwanted, and therefore uncontrolled impurities can obscure the effects investigated.

# 7616 THE THEORY OF GALVANOMAGNETIC EFFECTS IN SEMICONDUCTORS AND METALS SITUATED IN A STRONG ELECTRICAL FIELD. F.G.Bass.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 966-75 (1958). In Russian.

A determination is made of the dependence of the kinetic coefficients on the electric and magnetic fields for the case of non-linear dependence of the current on the electric field. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 1-15 (1958)].

# 7617 THE CHANGE OF THE ELECTRICAL RESISTIVITY OF FERROMAGNETIC METALS IN A RADIOFREQUENCY MAGNETIC FIELD. R.A.Dautov.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 999-1005 (1958). In Russian. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 39-45 (1958)].

# 7618 THE HALL EFFECT DUE TO MAGNETIZATION OF THIN NICKEL FILMS. G.Goureaux and A.Colombani.

C.R. Acad. Sci. (France), Vol. 252, No. 4, 516-18 (Jan. 23, 1961). In French.

Measurements were made of the "extraordinary" Hall constant and the field parameter as a function of film thickness and temperature. The results were qualitatively in agreement with theory, but a complete verification was not possible.

C.Hilsum

# 7619 MAGNETORESISTANCE OF THIN FILMS OF NICKEL: LONGITUDINAL EFFECT. G.Goureaux.

C.R. Acad. Sci. (France), Vol. 252, No. 6, 858-60 (Feb. 6, 1961). In French.

At normal temperatures the longitudinal magnetoresistance measured up to 10 000 c/s is positive and becomes negative near the Curie temperature. In contrast to some previous results, the existence of a significant coercive force in thin nickel films is demonstrated.

C.A.Hogarth

# 7620 INFLUENCE OF CONDUCTIVITY GRADIENTS ON GALVANOMAGNETIC EFFECTS IN SEMICONDUCTORS.

R.T.Bate and A.C.Beer.

J. appl. Phys. (USA), Vol. 32, No. 5, 800-5 (May, 1961).

An approximate solution is found of a boundary-value problem arising from the continuity equation in an inhomogeneous semiconductor, leading to rotational current vectors. Results are used to predict the effect of carrier-concentration gradients on magnetoresistance. The predicted weak-field effects are especially significant in degenerate semiconductors and n-type III-V intermetallics where the "intrinsic" magnetoresistance is small. In strong fields, even small gradients in carrier concentration can completely alter the field dependence of the magnetoresistance. Experimental results indicate that transverse currents, which do not occur in the simple case discussed, do appear in general, and further perturb the magnetoresistance. The influence of inhomogeneous magnetic fields is discussed briefly.

# 7621 MAGNETORESISTANCE OF HIGH PURITY InSb IN THE QUANTUM LIMIT. R.J.Sladek.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 1-9 (Nov., 1960).

Magnetoresistance measurements were made on high purity n-type InSb between 111°K and 50°K using magnetic field strengths up to 28 kG. The results are in qualitative agreement with theory for the quantum limit for the case of piezoelectric scattering and

classical statistics. Collision broadening seems to be the mechanism preventing the resistivity in a transverse field from diverging. Limitations on the comparison of the data with theory are discussed.

**7622 THE HALL EFFECT OF Cu AND Ag AND OF SOME OF THEIR DILUTED ALLOYS AT LOW TEMPERATURES.** B.Franken and G.J.van den Berg.

Physica (Netherlands), Vol. 26, No. 12, 1030-40 (Dec., 1960).

Measurements are reported on the Hall coefficient of polycrystalline samples of pure Cu and Ag and of some of their diluted alloys, in particular Ag-Mn (0.01-4 at.%). It was possible to attain a high sensitivity of  $10^{-10}$  V by using an alternating current of low frequency in a bridge circuit. For the pure metals the Hall coefficients are found to be field dependent with great variations from sample to sample. This may perhaps be connected with differences in texture of the polycrystalline samples. In the diamagnetic alloys Ag-Au and Cu-Sn no field dependence was found. The Hall voltage of the Ag-Mn alloys can generally be considered as the sum of two terms, one of which has a normal character, while the second one is proportional to the magnetization due to the manganese content. For the most diluted alloys, however, such a simple description does not apply.

**7623 TRANSVERSE-EVEN VOLTAGE: A HIGH-FIELD GALVANOMAGNETIC EFFECT ASSOCIATED WITH OPEN ORBITS IN METALS.** J.R.Klauder and J.E.Kunzler.

Phys. Rev. Letters (USA), Vol. 6, No. 4, 179-82 (Feb. 15, 1961).

The authors measured at 4.2°K a transverse-even voltage effect in high-purity magnetic fields in high-purity copper single crystals [ $\rho(300^\circ\text{K})/\rho(4.2^\circ\text{K}) = 8000$ ]. It is shown how the effect can be used to deduced open orbit directions from limited experimental data. It is also much more sensitive than the transverse magnetoresistance to higher-order open orbits. The effect is implicit in the work of Lifshits and Peshanskii (Abstr. 2358 of 1959).

M.G.Priestley

**7624 THE ELECTRICAL CONDUCTIVITY OF MICA UNDER STRONG ELECTRIC FIELDS.** B.Popov.

C.R.Acad. Bulg. Sci., Vol. 13, No. 4, 387-90 (July-Aug., 1960). In Russian.

Experimental measurement of the electrical conductivity of mica (muscovite) subjected to electric fields of 0.1 to 1.2 MV/cm and over a temperature range of 100 to 300°C. Two distinct regimes can be distinguished corresponding to the theories of Pool and Frenkel respectively. By varying the temperature a transition region between the two could be obtained. In this region the conductivity as calculated from a formula of Gubanov was found to be in excellent agreement with the measured value.

A.E.I.Research Laboratory

**7625 TRANSFERENCE NUMBER MEASUREMENTS FOR ALUMINIUM OXIDE.** W.D.Kingery and G.E.Meiling.

J. appl. Phys. (USA), Vol. 32, No. 3, 556 (March, 1961).

Careful experiments on single crystal sapphire disks lead to the conclusion that the ionic transport number in  $\text{Al}_2\text{O}_3$  at high temperatures is  $\leq 0.05$ , the limit of experimental accuracy.

C.A.H.garth

**7626 THE DEPENDENCE OF THE CONDUCTIVITY OF CELLULOSE, SILK AND WOOL ON THEIR WATER CONTENT.** E.J.Murphy.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 115-22 (Nov., 1960).

Deals with the effect of adsorbed water on the conductivity of such substances as cellulose, silk and wool. The water is adsorbed internally, that is, on internal surfaces, and is in equilibrium with the relative humidity of the air. It is shown that the conductivity  $\sigma$  is given by  $\sigma = \sigma_s(\alpha/\alpha_0)^n$ , where  $\sigma$  is expressed in  $(\text{ohm.cm})^{-1}$ ,  $\alpha$  is the water content in per cent of the dry weight,  $\alpha_0$  is the water content at saturation,  $\sigma_s$  is the "saturation conductivity", and  $n$  is a constant which has the following values: 9.3 for cellulose, 16.0 for silk and 16.4 for wool. The model used to explain these relations assumes that the secondary structure of these materials is such that there are periodically distributed ion-generating sites where the dissociation energy for the formation of ions is appreciably less than the energy required to dissociate a water molecule into  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$ . These ion generating sites are connected by a chain of  $n$  water-adsorption sites. The elementary contribution to the conductivity occurs when there is a complete chain of water molecules connecting neighbouring ion-generating sites. This condition prevails in general only for a small fraction of the time, and the conductivity is proportional to this fraction. The probability of occupancy of a

given adsorption site by a water molecule is, by definition,  $\alpha/\alpha_0$ , and the probability of simultaneous occupancy of  $n$  sites is  $(\alpha/\alpha_0)^n$ . The adsorption complex is considered to have the conduction properties of a solid dielectric, and the general expression for ionic conductivity may be substituted for  $\sigma_s$ , giving a complete expression for the conductivity. The model requires that  $n$  be an integer, and therefore the theoretical value of  $n$  for cellulose is 9, for silk 16 and for wool 16, in reasonable agreement with the experimental values. Silk and wool are representative of classes of proteins, and it is possible that other proteins will exhibit other values of the index  $n$ .

**7627 TEMPERATURE DEPENDENCE OF ELECTRON-BOMBARDMENT-INDUCED CONDUCTIVITY IN  $\text{MgO}$ .** W.C.Schieve and M.A.Pomerantz.

Phys. Rev. (USA), Vol. 122, No. 3, 808-14 (May 1, 1961).

Previous measurements (Abstr. 6174 of 1957) of the temperature dependence of the electrical conductivity induced in single crystals of  $\text{MgO}$  by bombardment with 1.3 MeV electrons over the temperature range 290°-600°K are extended to 100°K. Two crystals from different sources were investigated. The bombardment-induced current,  $I_c$ , varies linearly with primary current,  $I_p$ , at 298° and at 105°K. However, in certain cases measurements of  $I_c$  versus applied voltage,  $V_c$ , reveal a deviation from Ohmic behavior which is enhanced at low temperature. The bombardment-induced conductivity exhibited a maximum near 250°K. Both crystals displayed a temperature dependence at low temperatures which is consistent with the power-law relationship  $I_c/I_p = kT^m$ , where  $m = 3.3$  and 3.8, respectively. A rising non-Ohmic  $I_c$  versus  $V_c$  characteristic appears to be dependent upon the magnitude of the applied field, the onset occurring at  $3 \times 10^4$  V/cm. Collision ionization and warm carrier phenomena, rather than surface effects, probably account for the observed results. It is impossible to ascribe the temperature dependence of the bombardment-induced conductivity solely to the temperature variation of the carrier mobility. The results can be explained in terms of change with temperature of both the lifetime and mobility of the charge carriers. A combination of optical model (polaron), acoustical mode, and ionized impurity scattering is assumed, in addition to a temperature-dependent capture cross-section for the carrier. The theoretical curve fits the experimental data satisfactorily, and gives reasonable values for the parameters.

**7628 MECHANISMS OF SPACE-CHARGE-LIMITED CURRENT IN SOLIDS.** G.T.Wright.

Solid-State Electronics (GB), Vol. 2, No. 2-3, 165-89 (March, 1961).

The practical case is taken of a wide band-gap, high-resistivity material containing empty shallow trapping states but in which empty deep trapping states are eliminated by the mechanism of defect compensation. One-dimensional and one-carrier (electron) current through a plane parallel crystal is considered for the case when one contact is ohmic and one contact is blocking. At small forward voltage, current occurs by the predominant mechanism of carrier diffusion and increases approximately as the exponential of applied voltage; in this range, current is very sensitive to temperature changes. At large forward voltage, current occurs by the predominant mechanism of carrier drift and, after a voltage threshold due to the work-function difference between anode and cathode metals, increases very nearly as the square of applied voltage; this result is the solid-state analogue of the three-halves lower law for space-charge-limited current in vacuum. In this range current varies as the inverse cube of crystal thickness and is relatively insensitive to temperature changes. Between these two current ranges a smooth transition occurs from a diffusion to a drift mechanism of current and a "virtual cathode" is established in the crystal; there is no evidence for the existence of a negative-resistance region during the transition as predicted by Skinner (1955). Analytic expressions are derived describing forward current-voltage characteristics in the exponential and square-law ranges; they show that, depending mainly on crystal thicknesses, high forward conductance or high forward resistance can be achieved. With a strongly blocking anode, reverse current is always very small and very high rectification ratios can be achieved. For current in the square-law range the Fermi level is nearly constant through the crystal, except near the cathode and anode contacts. The discussion is illustrated with numerical results calculated on the basis of an electron mobility of  $1000 \text{ cm}^2/\text{V sec}$  which is intermediate between the value of  $200 \text{ cm}^2/\text{V sec}$  for cadmium sulphide and  $9300 \text{ cm}^2/\text{V sec}$  for gallium arsenide. In conclusion, some possible applications are considered for space-charge-limited current in fundamental solid-state research. 34 references.

# 7629 CHARGE EFFECTS DURING INHOMOGENEOUS DEFORMATION OF ROCKSALT.

F.Rueda and W.Dekeyser.

Phil. Mag. (GB), Vol. 6, 359-64 (March, 1961).

The electrical charge flow associated with an inhomogeneous plastic deformation, as first described by Fishbach and Nowick (Abstr. 10073 of 1955; 8094 of 1959), was further investigated. Microindentations were made in order to localize the deformation to a single small volume. In these conditions the observed effect corresponds qualitatively to a transport of negative charge by moving dislocations. Small additions of cadmium ions enhance the effect slightly. Flexion gives strong but non-reproducible signals.

# 7633 CARRIER DENSITY FLUCTUATIONS IN SEMICONDUCTORS AND PHOTOCONDUCTORS WITH ONE KIND OF TRAPPING CENTERS.

F.M.Klaassen, K.M.van Vliet and J.Blok.

Physica (Netherlands), Vol. 26, No. 8, 605-17 (Aug., 1960).

Applying the general theory of carrier density fluctuations in semiconductors (Abstr. 8753 of 1958), based on the formalism of irreversible thermodynamics, expressions for the matrix elements of carrier density fluctuations and for the relaxation times are given in the case of semiconductors with one kind of trapping- or recombination centres. These expressions are approximated in some cases by formulae that can be verified experimentally, for instance trapping of minority carriers in deep lying centres (occurring in PbS photoconductors) and trapping of carriers at shallow traps in nearly intrinsic semiconductors. With the aid of the extended g-r theorem it is finally proved that the derived expressions for the noise in semiconductors hold for photoconductors only if the centres act as traps.

# THEORY OF GALVANOMAGNETIC EFFECTS IN SEMICONDUCTORS.

See Abstr. 7616

# 7634 PHOTOTHERMAL EFFECT IN SEMICONDUCTORS.

W.W.Gärtner.

Phys. Rev. (USA), Vol. 122, No. 2, 419-24 (April 15, 1961).

When a sample of semiconducting material is illuminated, pairs of excess carriers are generated which diffuse through the material according to the density gradients established. Each pair carries an energy approximately equal to the band gap of the material. This energy is deposited where the excess electron recombines with a hole and causes local heating of the lattice. A temperature distribution will therefore be established in the sample which depends on the characteristics of optical absorption and bulk and surface recombination in and on the sample. This establishment of a temperature distribution in a solid by optically excited diffusing and recombining carriers is called the photothermal effect. The paper gives a formulation of the theory governing the photothermal effect, and the case of small temperature elevations in an infinite slab is worked out in detail.

# 7630 INFLUENCE OF PRESSURE ON PROPERTIES OF SEMICONDUCTORS.

J.Robin.

J. Phys. Radium (France), Vol. 21, No. 2, 130-40 (Feb., 1960). In French.

Effects on electrical conductivity, resistivity of p-n junctions and the absorption edge of the fundamental band are summarized. This influence is indicated by the variation of the width of the energy gap sometimes accompanied by a change of the mobilities of electron and holes.

# ELECTRON EMISSION FROM P-N JUNCTIONS.

See Abstr. 7089

# 7631 NOTE ON SEMICONDUCTOR STATISTICS.

S.Teitler and R.F.Wallis.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 71-5 (Nov., 1960).

The Guggenheim method (see Abstr. 8400 of 1953) for treating semiconductor statistics using the grand partition function is applied to multi-level impurities in Ge assuming a model for electron configuration at the impurity based on the present knowledge of the energy band structure of Ge. The results are expressed in terms of effective one-electron energies corresponding to the one-electron levels associated with the impurities. The difference between these effective one-electron energies and actual one-electron energies is emphasized.

# 7632 THEORY OF AUGER NEUTRALIZATION OF IONS AT THE SURFACE OF A DIAMOND-TYPE SEMICONDUCTOR.

H.D.Hagstrum.

Phys. Rev. (USA), Vol. 122, No. 1, 83-113 (April, 1961).

The two-electron, Auger-type transitions which occur when an ion of sufficiently large ionization energy is neutralized at the atomically clean surface of a diamond-type semiconductor are discussed. Consideration of the basic elements of the problem leads to a computing programme which enables one to calculate the total electron yield and kinetic energy distribution of ejected electrons in terms of a number of parameters. It is possible to account for the experimental results for singly-charged noble gas ions incident on the (111) faces of Si and Ge and the (100) face of Si. The fit of theory to experiment is unique in its principal features yielding numerical results concerning: (1) the state density function for the valence bands of Si and Ge, (2) the energy dependence of the matrix element as it is determined by symmetry of the valence band wave-functions, (3) the effective ionization energy near the solid surface, (4) energy broadening, and (5) electron escape over the surface barrier. Overall width of the valence band is found to be 14-16 eV for both Si and Ge. Width of the degenerate p bands is 5.1 eV in Si, 4.3 eV in Ge. The matrix element for p-type valence electrons is 0.3 times that for s-type valence electrons. Effective ionization energy is 2.2 eV less than the free-space value for 10 eV He<sup>+</sup> ions and decreases linearly with ion velocity. Energy broadening is small for 10 eV ions and increases approximately linearly with ion velocity. Probability of electron escape is several times that predicted for an isotropic distribution of excited electrons incident on a plane surface barrier. A general theory of Auger neutralization is given in which the conclusions of the fit to experiment are interpreted. Investigation of the matrix element as a Coulomb interaction integral involving wave-functions whose general characteristics are known but which are not explicitly evaluated leads to an understanding of its principal dependences on energy and angle.

## Semiconducting Materials

# 7635 OPTICAL ABSORPTION AND RECOMBINATION RADIATION IN SEMICONDUCTORS DUE TO

TRANSITIONS BETWEEN HYDROGEN-LIKE ACCEPTOR IMPURITY LEVELS AND THE CONDUCTION BAND. D.M.Eagles.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 76-83 (Nov., 1960).

A simplified theory is given of the expected form of the optical absorption and recombination radiation spectra due to direct transitions between hydrogen-like acceptor levels and the conduction band in a semiconductor with simple bands. Some necessary modifications to the simple theory are discussed, and it is shown that transitions from acceptor levels could be the cause of an observed shift of the absorption edge to longer wavelengths on passing from n- to p-type GaAs. For recombination radiation, some experimental curves on the III-V compounds which probably involve transitions to impurity levels are rather broader than those predicted by the simple theory.

# 7636 RELATION BETWEEN SURFACE CONCENTRATION AND AVERAGE CONDUCTIVITY IN DIFFUSED LAYERS

IN GERMANIUM. D.B.Cuttriss.

Bell Syst. tech. J. (USA), Vol. 40, No. 2, 509-21 (March, 1961).

An expression is derived for the average conductivity of a diffused layer in semiconductor material as a function of the surface concentration of the diffused impurity and the background impurity concentration. Curves are presented depicting the relationship among these parameters for the case of germanium. Included are curves for both diffused impurity types for the complementary error function, gaussian, exponential and linear impurity distributions.

# 7637 THE ENERGY DISTRIBUTION OF ELECTRON STATES ON THE SURFACE OF GERMANIUM IN VERY HIGH VACUUM.

N.S.Chernaya.

Fiz. tverdogo Tela (USSR), Sbornik [Supplement] II, 79-82 (1959). In Russian.

Reports that an etched surface of p-type Ge has two types of surface level in high vacuum ( $1-2 \times 10^{-9}$  mm Hg): donor levels of  $(1.3 \pm 0.1) \times 10^{12}$  cm<sup>-2</sup> density and 0.14  $\pm$  0.01 eV depth, and acceptor levels of  $(8 \pm 1) \times 10^{12}$  cm<sup>-2</sup> density and 0.30  $\pm$  0.02 eV depth.

A.Tybulewicz

- 7638 CONFIRMATION OF LIFETIMES BY NOISE AND BY HAYNES-SHOCKLEY METHOD. S.Okazaki.  
J. appl. Phys. (USA), Vol. 32, No. 4, 712-13 (April, 1961).

Values of minority carrier lifetime in germanium filaments deduced from noise produced by photogeneration of carriers agree well with the values obtained by the Haynes-Shockley method (Abstr. 4381 of 1951).

- 7639 A.C. AND D.C. FIELD EFFECTS ON CLEANED GERMANIUM SURFACES. S.Kawaji.

J. Phys. Soc. Japan, Vol. 15, No. 1, 95-9 (Jan., 1960).

Reports measurements of the a.c. and d.c. field effects on electrical conductance of germanium surfaces cleaned by Joule heating up to about 800°C in ultra-high vacuum. In a.c. fields a minimum of conductance (showing the surface was slightly n-type) was observed and the density of fast states was estimated at  $1.7 \times 10^{13} \text{ cm}^{-2} \text{ V}^{-1}$ . When the surface was exposed to oxygen, the fast state density decreased down to  $2.4 \times 10^{12} \text{ cm}^{-2} \text{ V}^{-1}$  and the surface potential decreased by 0.03 V. These results suggest that the fast states are dangling bonds at the surface. In measurements of the d.c. field effect, no appreciable change of conductance occurred in vacuum. The slow decay appeared when the surface was exposed to air. These results show that the slow states should be attributed to adsorbed gases on the outer surface of the oxide layer on germanium.

- 7640 GALVANOMAGNETIC EFFECTS IN n-Ge IN THE IMPURITY CONDUCTION RANGE.

R.J.Sladek and R.W.Keyes.

Phys. Rev. (USA), Vol. 122, No. 2, 437-42 (April 15, 1961).

Measurements of the magnetoresistance and magnetic field dependence of the Hall coefficient of several samples of n-type germanium in the impurity conduction range were made employing magnetic field strengths up to 28 kG. The magnitude and the crystal-line anisotropy of the magnetoresistance are interpreted in terms of the changes in the donor wave-functions which are produced by the magnetic field. The field dependence of the Hall coefficient is interpreted as a magnetoresistance effect of the conduction band.

- CONDUCTION IN  $\gamma$ -RAY IRRADIATED GERMANIUM.  
See Abstr. 7609

- 7641 THEORY OF ELECTRICAL CONDUCTIVITY OF GERMANIUM AND SILICON. I. THE ELECTRON-PHONON MATRIX ELEMENT. W.Klose.

Ann. Phys. (Germany), Vol. 7, No. 5-6, 233-42 (1961). In German.

Electron-phonon matrix elements are calculated using the Nordheim potential. Notable contributions to the scattering via the processes between energy valleys, and via normal processes within a valley, are found. Corresponding matrix elements for Ge and Si are compared.

P.T.Landsberg

- 7642 USE OF HALL MEASUREMENTS IN EVALUATING POLYCRYSTALLINE SILICON.

P.J.Olshefski, D.J.Shombert and I.R.Weingarten.

J. Electrochem. Soc. (USA), Vol. 108, No. 4, 362-5 (April, 1961).

Hall measurements at room temperature were used to determine the average net carrier density in polycrystalline silicon. The method did not require cutting of samples and destruction of the rods. Current contacts were made to the ends of a rod with strips of metal foil; Hall contacts were made with two titanium blades which closed on the rod. Hall measurements made this way on single-crystal zone-refined rods agreed with measurements on samples cut from the rods in the conventional manner. The average carrier densities measured in the polycrystalline rods were correlated with the resistivities of these same rods after one, two, three floating zone passes.

- 7643 DETAILED ANALYSIS OF THIN PHOSPHORUS-DIFFUSED LAYERS IN p-TYPE SILICON.

E.Tannenbaum.

Solid-State Electronics (GB), Vol. 2, No. 2-3, 123-32 (March, 1961).

Detailed concentration profiles of phosphorus-diffused layers in p-type silicon were obtained using a new, accurate technique. The phosphorus distributions were found to be significantly different from those predicted by simple theory in that: (1) under conditions of constant surface concentration, they do not obey the predicted error-function complement; (2) the diffusion coefficient is a constant up to a concentration of about  $10^{20} \text{ cm}^{-3}$ , but is a strong function of concentration above that value, and the variation is larger than can be accounted for by field-accelerated diffusion; (3) at high concentrations, there is a difference between the phosphorus concentration determined from resistivity measurements and that

determined from radioactive tracer measurements. Electron mobility values in the concentration range above  $10^{20} \text{ cm}^{-3}$  were obtained from the data. The experimental results suggest that there is a limit to the concentration of electrically active phosphorus that can be obtained in silicon, and that this limit has been observed.

- 7644 SEMICONDUCTING PROPERTIES OF INORGANIC AMORPHOUS MATERIALS. H.L.Uphoff and J.H.Healy.  
J. appl. Phys. (USA), Vol. 32, No. 5, 950-4 (May, 1961).

Ten compositions were prepared in the systems As-Se-Te and As-S-Te. Nine of these compositions were amorphous in structure. The resistivities and Seebeck coefficients of these materials were measured as functions of temperature. The resistivity varied exponentially with temperature, while the Seebeck coefficient varied linearly. At 298°K, the resistivity values for the amorphous samples ranged from  $4.7 \times 10^4$  to  $2.5 \times 10^{13} \text{ ohm cm}$ , while the Seebeck coefficient values ranged from 830-1625  $\mu\text{V deg}^{-1} \text{ K}$  (p type). At any temperature, the resistivity decreased with increase in tellurium content. For the amorphous materials, the thermal conductivity values ranged from 2.4 to 4.4  $\text{mW cm}^{-1} \text{ deg}^{-1} \text{ K}$ .

- 7645 GALVANOMAGNETIC PROPERTIES OF n-TYPE CdAs<sub>2</sub>. A.S.Fischler.

Phys. Rev. (USA), Vol. 122, No. 2, 425-9 (April 15, 1961).

Galvanomagnetic measurements on oriented, single crystals of n-type CdAs<sub>2</sub>, a noncubic semiconductor, indicate surfaces of constant energy to be ellipsoids of revolution, located along the symmetry axis of the crystal system. The ratio of electronic mobility is found to be  $\mu_{11}/\mu_{\perp} \sim 4$ , from Hall and resistivity data. Magnetoresistance measurements confirm this conduction-band model and indicate the scattering to be due primarily to acoustical lattice modes with some degree of impurity scattering.

- 7646 ELECTRICAL CONDUCTIVITY OF SINGLE-CRYSTAL CUPROUS OXIDE AT HIGH TEMPERATURES.

R.S.Toth, R.Kilkson and D.Trivich.

Phys. Rev. (USA), Vol. 122, No. 2, 482-8 (April 15, 1961).

The electrical conductivity was measured in the temperature range 1100° to 500°C in oxygen pressures from 152 mm to  $10^{-5}$  mm of Hg. The  $\log \sigma$  versus  $\log P(\text{O}_2)$  curves were found to be linear between the oxygen pressures of 50 and  $10^{-2}$  mm, with an average slope of 0.1420, or approximately 1/7. These curves exhibit a radical change in slope at  $\text{O}_2$  pressures below  $10^{-2}$  mm. The plots of  $\log \sigma$  versus  $1/T$  at constant oxygen pressure were found to be linear and the activation energies obtained from the slopes of these plots have an average value of 0.65 eV at  $\text{O}_2$  pressures between 50 and  $10^{-2}$  mm. At  $\text{O}_2$  pressures of  $10^{-3}$  to  $10^{-4}$  mm, the activation energy obtained from the measurement of single-crystal  $\text{Cu}_2\text{O}$  in air at temperatures from 1020° to 1100°C was found to have an average value of 0.767 eV. An explanation for the physical significance of the activation energies obtained is suggested and the model proposed to explain the dependence of the electrical conductivity on the  $\text{O}_2$  pressure are considered.

- 7647 DISTRIBUTION COEFFICIENTS OF IMPURITIES IN GALLIUM ANTIMONIDE. R.N.Hall and J.H.Racette.

J. appl. Phys. (USA), Vol. 32, No. 5, 856 (May, 1961).

Distribution coefficients of several group II, IV and VI elements in GaSb are reported, and some of the physical properties of this material are discussed briefly.

- 7648 EVIDENCE FOR STATES (BANDS) IN THE FORBIDDEN GAP OF DEGENERATE GaAs AND InP — SECONDARY TUNNEL CURRENTS AND NEGATIVE RESISTANCES.

N.Holonyak, Jr.

J. appl. Phys. (USA), Vol. 32, No. 1, 130-1 (Jan., 1961).

Measurements of tunnel diode characteristics at 78°K show that secondary humps in the valley part of the characteristics and also the large valley currents sometimes observed may arise from discrete states or bands in the forbidden gap which aid in secondary tunnelling. This raises the question whether one can describe a forbidden gap for a highly degenerate semiconductor.

C.A.Hogart

- 7649 THERMAL AND ELECTRICAL CONDUCTIVITIES, HALL EFFECT AND THERMOELECTRIC POWER OF InSb.

G.Busch and E.Steigmeier.

Helv. phys. Acta (Switzerland), Vol. 34, No. 1, 1-28 (1961).

Single crystal InSb was studied between 195° and 715°K. With increasing temperature, the thermal conductivity decreases, but does not show the large high-temperature anomaly previously found by Busch and Schneider (Abstr. 3727 of 1955) and by Weiss (Abstr.

12167 of 1959). The observed thermal conductivity is assumed to be the sum of a lattice component and a part due to the carriers. The latter is calculated on the basis of the band model using the measured electrical conductivity. The contribution due to the transport of gap energy is small compared with the Wiedemann-Franz part at nearly all temperatures. Between 200° and 400°K, the thermal conductivity of the lattice is proportional to  $T^{-11}$ , whilst for higher temperatures a departure from this law is observed. For this a satisfactory explanation may be given. The calculation of the lattice contribution after Leibfried and Schloemann (Abstr. 282 of 1956) leads at 400°K to the observed value when a Grueneisen constant of 2.0 is used. The electron mobility determined from Hall coefficient and electrical conductivity is in good agreement with the theoretical values of Ehrenreich (Abstr. 8130 of 1959) and the measurements of Hrostowski et al. (Abstr. 2108 of 1956).

7650 INFLUENCE OF MAGNETOCONDUCTIVITY DISCONTINUITIES ON GALVANOMAGNETIC EFFECTS IN INDIUM ANTIMONIDE. R.T.Bate, J.C.Bell and A.C.Beer. J. appl. Phys. (USA), Vol. 32, No. 5, 806-14 (May, 1961).

Anomalous galvanomagnetic effects associated with spatial discontinuities in carrier concentration were observed in n-type InSb. These discontinuities result from anisotropic segregation of impurities during crystal growth. An increase in the magnitude of the Hall coefficient at 20 000 G to nearly twice the weak-field value was observed in one case. The magnetoresistance is especially sensitive to inhomogeneities. For an inhomogeneous sample at a particular magnetic field, the measured  $\Delta\rho/\rho_0$  may be as much as 100 times larger than that for a homogeneous sample. Negative magnetoresistance was also observed at room temperature in inhomogeneous samples. All of the above observations are predicted qualitatively by considering a simple model consisting of a long, thin specimen having a discontinuity in resistivity and Hall coefficient in the current direction. The boundary value problem corresponding to this case is solved to predict the electric field and current densities.

7651 PREPARATION AND PROPERTIES OF GROWN P-N JUNCTIONS OF InSb.

H.C.Gorton, A.R.Zacarani, F.J.Reid and C.S.Peet. J. Electrochem. Soc. (USA), Vol. 108, No. 4, 354-6 (April, 1961).

Grown p-n junctions of InSb were produced by doping high-purity n-type melts with zinc. The crystals were oriented such that the growth axes of the crystals were perpendicular to a (111) plane. The effects of anisotropic distribution of impurities within the crystals were observed in the electrical properties of the diodes. The lifetime of minority carriers at high injection levels (forward bias) was observed. Anomalous values are attributed to changes in properties of the bulk material rather than the surface. The curves of current density as a function of temperature showed leakage currents to predominate at lower temperatures and saturation currents to predominate at higher temperatures. This observation was verified by current-voltage profiles at appropriate temperatures.

7652 SOME ELECTRICAL AND OPTICAL PROPERTIES OF InSb-In<sub>2</sub>Te<sub>3</sub> ALLOYS.

J.C.Woolley, C.M.Gillett and J.A.Evans. J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 138-43 (Nov., 1960).

The range of solid solution at the InSb end of the InSb-In<sub>2</sub>Te<sub>3</sub> alloy system was determined by X-ray methods to be about 15 mol.% In<sub>2</sub>Te<sub>3</sub>, and the electrical and optical properties of the alloys in this range were investigated. It was found from the electrical measurements of Hall effect and conductivity that for small percentages of In<sub>2</sub>Te<sub>3</sub> (approximately less than 0.5 mol.%) the added tellurium atoms act as donors in the InSb giving carrier densities of approximately  $10^{19}$  cm<sup>-3</sup>. At higher percentages of In<sub>2</sub>Te<sub>3</sub> this number of carriers is still present but the rest of the In<sub>2</sub>Te<sub>3</sub> alloys with the InSb give vacancies on the indium sublattice. These results were confirmed by the infrared transmission measurements. It was found that in the composition range where the alloying effect predominates the Hall mobility is proportional to  $N^{-1/3}$  where N is the fraction of sites vacant on the indium sublattice.

7653 PROPERTIES AND APPLICATIONS OF INDIUM ANTIMONIDE. R.E.J.King and B.E.Bartlett. Philips tech. Rev. (Netherlands), Vol. 22, No. 7, 217-25 (1960-61).

InSb has a small band gap and is therefore a good photoconductor. The Mullard ORP 10 InSb cell is sensitive to wavelengths up to 7.5  $\mu$ , i.e. to further in the infrared than any other cell. The liquid-nitrogen-cooled cell ORP 13 is characterized by a particularly

high sensitivity, viz. 14 mV per  $\mu$ W at 4  $\mu$ . The time constants of these two cells are, respectively, <1  $\mu$ sec and <10  $\mu$ sec. The electron mobility in pure InSb is very high (650 000 cm<sup>2</sup>/Vs at 77°K), so that it is also a very suitable material for Hall-effect devices. Still other applications depend on the large magnetoresistance effect in InSb. Very pure InSb single crystals are prepared by melting together purified In and Sb, zone-melting of the compound, and then crystal-pulling on the (211) plane. P-type material is made by doping with e.g. germanium.

7654 THE SEMICONDUCTIVITY OF ORGANIC SUBSTANCES. III. HAEMOGLOBIN AND SOME AMINO ACIDS.

M.H.Cardew and D.D.Eley.

Disc. Faraday Soc. (GB), No. 27, 115-28 (1959).

"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 4920 of 1961). For Pt II, see Trans. Faraday Soc. (GB), Vol. 51, 152 (1955). Conductance data were established for haemoglobin, globin, ferrihaem and a number of amino acids in the solid dry state in vacuo. Energy-gaps determined by temperature variation of the conductance are, for example: globin 2.97 eV, haemoglobin 2.75 eV, ferrihaem 1.74 eV, glycine 2.92 eV, polyglycine 3.12 eV; ferrihaem falls into the group of molecules, such as phthalocyanine, where conductance is due to  $\pi$ -electrons in the conjugated carbon double bonds. The other substances have a much lower conductance, and it is suggested that they are intrinsic semiconductors, due to electron mobility in the CO...HN hydrogen bridge system. The relatively small difference between haemoglobin and globin is attributed to the increased degree of denaturation of the globin specimen, with consequent disordering of the H-bridge system. Thermo-electric power measurements denotes glycine as n-type, and haemoglobin as p-type, the values being small as expected for intrinsic semiconductors. The haemoglobin result may arise from electron trapping by impurities resulting from the heat treatment, or possibly the haems. Conductance measurements along and across the (ac) plane in a single crystal of glycine support the H-bridge theory. The relation of electron mobility to energy gap is discussed and also the implications of the results for three biochemical problems.

7655 THE SEMICONDUCTIVITY OF ORGANIC SUBSTANCES. IV. SEMI-QUINONE TYPE MOLECULAR COMPLEXES.

D.D.Eley, H.Inokuchi and M.R.Willis.

Disc. Faraday Soc. (GB), No. 28, 54-63 (1959).

"Crystal imperfections" discussion (see Abstr. 2386 of 1961). The electrical conductivities of some molecular complexes of the donor-acceptor type between aromatic amines and halogenated p-benzo-quinones were examined by both a.c. and d.c. methods. The complexes were found to behave as semiconductors with an energy gap of approximately 0.5 eV. Complexes with a stronger electron donor show a much enhanced conductance and marked deviation from Ohm's law. These results are discussed in relation to the optical and magnetic properties of these compounds.

7656 ON SOME PROPERTIES OF SEMICONDUCTING POLYMER MATERIALS. R.M.Voitenko and E.M.Raskina.

Dokl. Akad. Nauk SSSR, Vol. 136, No. 5, 1137-8 (Feb. 11, 1961). In Russian.

The variation of electrical conductivity and thermoelectric power with temperature was examined for several specimens of polyacrylonitrile. The conductivity varies exponentially with temperature in the usual way whilst the thermoelectric power remains almost independent of temperature over the same range. This evidence is used to show that the conductivity variation with temperature is due to an exponential variation of carrier mobility.

K.N.R.Taylor

## Semiconductor Devices

7657 ANODIC DISSOLUTION OF GERMANIUM CONTAINING A P-N JUNCTION.

O.G.Deryagin, E.A.Paleolog and N.D.Tomashov.

Dokl. Akad. Nauk SSSR, Vol. 133, No. 2, 388-91 (July 11, 1960). In Russian.

Potential distribution and current density were studied for n- and p-type surface regions in the vicinity of In-alloyed p-n junctions in NaOH and H<sub>2</sub>SO<sub>4</sub> solutions (both 0.1 N). Current density was determined from changes in surface relief due to anodic attack, potential via a capillary probe. In NaOH solutions indium passivates, and so does n-type Ge except near a p-n junction where hole injection from

the p-region leads to anodic attack (contact was made via the indium). In  $\text{H}_2\text{SO}_4$  both In and p-type Ge are attacked. A grown junction showed similar behaviour. [English translation in: Soviet Physics-Doklady (USA)]. C.H.L.Goodman

7658 ELECTRON-EMISSION MICROSCOPE AND VELOCITY DISTRIBUTION STUDIES ON SILICON CARBIDE P-N JUNCTION EMITTERS. P.H.Gleichauf and V.Ozarow. J. appl. Phys. (USA), Vol. 32, No. 3, 549-50 (March, 1961).

The electron emission from a p-n junction on silicon carbide was observed in a low voltage electron microscope in which the junction was the cathode. The electron velocity distribution and the light emission from the same junction under the same bias conditions were also studied. The tangential velocity of the emitted electrons makes quantitative interpretation difficult, but an attempt is made to explain the difference between the operating voltage and the maximum energy of the emitted electrons in terms of the energy transfer occurring in collisions of the most energetic electrons or holes with bound electrons. V.E.Cosslett

7659 SOME EXPERIMENTS USING A VACUUM-CLEANED SILICON P-N JUNCTION. J.T.Law. J. appl. Phys. (USA), Vol. 32, No. 5, 848-55 (May, 1961).

Measurements of the junction characteristics and the transport properties on either side of a vacuum-cleaned silicon p-n junction were carried out. The changes in these properties during the adsorption of oxygen and hydrogen were also investigated. In the clean condition, the value of  $(E_F - E_V)$  for both 21.5 ohm cm n type and 27 ohm cm p type was found to be 0.13-0.14 eV. When the silicon surface was clean, a large excess current across the junction was observed which disappeared during the absorption of gas.

7660 OSCILLATIONS IN THE LONGITUDINAL TUNNEL CURRENT OF TUNNEL DIODES. R.R.Haering and P.B.Miller. Phys. Rev. Letters (USA), Vol. 6, No. 6, 269-71 (March 15, 1961).

The tunnel current in InSb tunnel diodes displays oscillations at low temperature in a large longitudinal magnetic field. It is pointed out that these oscillations cannot be of the De Haas-Van Alphen type because this would require that a large portion of the current was due to electrons with high magnetic quantum number, whereas the tunnelling process strongly favours the low quantum numbers. It is suggested that the effect is due instead to the small fluctuations of the Fermi level in a magnetic field. These fluctuations affect the capacitance of the junction and hence the average junction field. A quantitative theory is sketched. L.Pincherle

7661 MEASUREMENT OF TUNNEL DIODE NEGATIVE RESISTANCE. C.D.Todd. Rev. sci. Instrum. (USA), Vol. 32, No. 3, 338-41 (March, 1961).

Several methods for the measurement of  $r_d$ , the magnitude of tunnel diode negative resistance, are presented. A null indication technique capable of very accurate measurements is discussed along with necessary procedures to prevent oscillation. A test fixture which will allow stabilization of most tunnel diodes, even those for which the resistive cutoff frequency exceeds the self-resonant frequency, is described.

7662 THE DRIFT IN CHARACTERISTICS OF SILICON TRANSISTORS AS A FUNCTION OF TEMPERATURE AND OPERATING TIME. G.Giralt and J.C.Polisset. C.R. Acad. Sci. (France), Vol. 252, No. 4, 519-21 (Jan 23, 1961). In French.

Over a period of 100 hours the base current  $I_B$  and the current gain  $\beta$  showed changes of several per cent. The original characteristics returned if the transistor was left for a few months. The temperature dependence of the base-emitter voltage was about  $2\text{mV}/^\circ\text{C}$  for all the transistors examined, but the temperature dependence of  $I_B$  was small when  $\beta$  was large. C.Hilsum

NOISE IN TRANSISTORS, MASERS AND PARAMETRIC AMPLIFIERS. See Abstr. 7088

7663 PREPARATION AND STUDY OF HIGH-EFFICIENCY SILICON SOLAR BATTERIES. H.Valdman. C.R. Acad. Sci. (France), Vol. 252, No. 2, 246-8 (Jan. 9, 1961). In French.

Units with an efficiency of 14% can be made by diffusing phosphorus into p-type silicon, and removing the surface layer by etching. C.Hilsum

7664 INTRODUCTION TO TECNETRON THEORY. A.V.J.Martin.

J. Phys. Radium (France), Vol. 21, Suppl. No. 3, 24A-36A (March, 1960). In French.

The tecnetron is a semiconductor amplifying device. It uses the centripetal striction produced by the field effect in a cylindrical structure. Its analysis is divided into two sections. Section one establishes the approximative fundamental theory and deduces the principal characteristics of the device, as well as some practical conclusions. Section two deals with secondary effects and their bearing on the fundamental theory and the practical design of the device.

## Photoconductivity

7665 PREPARATION OF PHOTOCELLS FROM PRESSED CdSe POWDER. G.Bános, L.Gombay and I.Hevesi. Acta phys. chem. Szeged. (Hungary), Vol. 4, No. 3-4, 97-102 (1958). In German.

CdSe powder was produced from the reaction of  $\text{CdSO}_4$  with high-purity  $\text{H}_2\text{Se}$ . Au, Cu, or Al electrodes were evaporated on to pellets made by compressing the powder. In the dark the pellets (n- or p-type) were ohmic. Under illumination a photo-e.m.f., developed at the metal/semiconductor barrier layer, was observed. C.A.Hogart

7666 ON THE DIFFERENT FORMS OF THE SPECTRAL SENSITIVITY CURVES FOR THE PHOTOCONDUCTIVITY OF PURE CRYSTALS OF CADMIUM SULPHIDE. THE INFLUENCE OF CRYSTAL THICKNESS. E.Grillot, E.F.Gross, M.Bancie-Grillot and B.Novikov. C.R. Acad. Sci. (France), Vol. 252, No. 6, 864-6 (Feb. 6, 1961). In French.

Spectral sensitivities are given for two thicknesses of crystals ( $80\mu$  and  $500\mu$ ). The thinner crystal is more sensitive at short wavelengths and the thicker one at long wavelengths, but both curves have common kinks. See also following abstract. D.J.Oliver

7667 ON THE DIFFERENT FORMS OF SPECTRAL SENSITIVITY CURVES FOR THE PHOTOCONDUCTIVITY OF PURE CRYSTALS OF CADMIUM SULPHIDE. THE INFLUENCE OF THE POLARIZATION OF THE EXCITING RADIATION AND THE METHOD OF CRYSTAL PREPARATION. E.Grillot, E.F.Gross, M.Bancie-Grillot and B.V.Novikov. C.R. Acad. Sci. (France), Vol. 252, No. 8, 1129-31 (Feb. 20, 1961). In French.

It has been shown (see preceding abstract) that the long wavelength maximum in the wavelength dependence of the photocurrent of cadmium sulphide is displaced from 4870 to 4900 Å (at  $77^\circ\text{K}$ ) when the thickness of the single crystal is increased from  $80\mu$  to  $500\mu$ . Rotation of the plane of polarization of the exciting radiation from  $E||c$  to  $E\perp c$  produced a similar effect. The maximum for  $E||c$  occurred at the same wavelength as a pronounced minimum on the short-wavelength side of the  $E\perp c$  main peak. These results on slowly crystallized monocrystals are compared with those on crystals grown from the vapour phase and also by a sublimation process. The short-wavelength structure was less marked for the latter specimens, apparently because of larger concentrations of lattice defects. The positions of the main long-wavelength peaks are unaffected by the method of crystal preparation and it is suggested that they are characteristic of fundamental energy levels of the cadmium sulphide lattice, which involve exciton processes. P.J.Dean

7668 THE INFLUENCE OF INFRARED RADIATION ON THE PHOTOCONDUCTIVITY OF CADMIUM SULPHIDE SINGLE CRYSTALS. M.Borisov, I.Georgieva and M.Milyashev. C.R. Acad. Bulg. Sci., Vol. 13, No. 6, 661-4 (Nov.-Dec., 1960). In Russian.

It was established that infrared radiation exerts a destructive as well as a stimulative influence on the photoresistance of cadmium sulphide single crystals when the exposure is made in the direction of the electric field. The dependence of the transition from the destructive to the constructive effect was examined as a function of the voltage, wavelength and intensity of the infrared radiation. D.J.Huntley

7669 AN INVESTIGATION OF THE LUX-AMPERE CHARACTERISTICS OF CdS SINGLE CRYSTALS. E.A. Sal'kov and G.A. Fedorus. Fiz. tverdogo Tela (USSR), Vol. 2, No. 7, 1576-80 (July, 1960). In Russian.

Photocurrent ( $I$ ), photocurrent yield ( $a$ ), and photocarrier lifetime ( $\tau$ ) were measured as functions of illumination level ( $L$ ) of up to  $\sim 10^{13}$  quanta/sec (5300 Å radiation). Plots of  $I$  versus  $L$  usually had the same slope as those for the product ( $a \tau L$ ) versus  $L$ , but crystals quenched after heat treatment, and believed to contain a high concentration of traps, did not show this behaviour. The effect of infrared quenching (by 0.9  $\mu$  radiation) was also studied. The overall results are not compatible with constant quantum yield. [English translation in: Soviet Physics—Solid State (USA)].

C.H.L. Goodman

7670 THE EFFECT OF TRAPPING LEVELS ON THE RELAXATION OF NON-EQUILIBRIUM PHOTOCONDUCTIVITY IN GERMANIUM IRRADIATED WITH  $\gamma$ -RAYS. S.M. Ryvkin and I.D. Yaroshetskii. Fiz. tverdogo Tela (USSR), Vol. 2, No. 8, 1966-77 (Aug., 1960). In Russian.

Studies of the relaxation of photoconductivity in n-type germanium showed that  $\gamma$ -ray irradiation produced vacancies which gave rise to recombination and trapping levels. At low temperatures the trapping levels were transformed into recombination levels. [English translation in: Soviet Physics—Solid State (USA)].

A. Tybulewicz

7671 CURRENT NOISE AND DISTRIBUTED TRAPS IN CADMIUM SULFIDE. J.J. Brophy. Phys. Rev. (USA), Vol. 122, No. 1, 26-30 (April 1, 1961).

The high-frequency portion of the current noise spectrum observed in lightly doped CdS single crystals under uniform 5200 Å illumination is characteristic of electron trapping transitions to shallow levels. In many crystals the noise spectra have a characteristic  $1/f$  trend when the electron quasi-Fermi level is not located near a discrete trap. The  $1/f$  trapping noise observed in one crystal at temperatures of 10°, 27° and 52° C, and for 20 different positions of the electron quasi-Fermi level between 0.5 and 0.3 eV below the conduction band, can be represented by a single expression of the form  $(1/\omega) \tan^{-1} \omega \tau$ , where  $\tau$  is determined by the low-frequency turnover of the  $1/f$  trapping noise. From these experimental values of  $\tau$ , trap depths are calculated which are in good agreement with the positions of discrete trapping levels determined from other measurements. Since the low-frequency turnovers of the  $1/f$  spectra are thus related to the discrete traps, rather than to the position of the electron quasi-Fermi level directly it appears that the  $1/f$  noise may not be associated with a postulated continuous distribution of traps in energy, but rather with a dispersion of capture and release times into the discrete traps.

7672 VARIATION OF PHOTOVOLTAIC RESPONSE WITH MAGNETIC FIELD FOR A GERMANIUM p-n JUNCTION. W. Dunstan. Proc. Phys. Soc. (GB), Vol. 77, Pt 2, 459-66 (Feb., 1961).

Measurements are described of the variation with magnetic field of the open-circuit voltage of a germanium p-n junction photocell, the illumination being parallel to the junction plane, and the field perpendicular to the illumination. The effect depends on the orientation of the field, vanishes when the latter is less than about 0.1 Wb/m<sup>2</sup>, and is proportional to illumination. A fairly complete discussion of the operation of the cell is attempted, both with and without field; a partial explanation of the results is obtained.

7673 PRODUCTION OF A PHOTOSENSITIVE SURFACE ON A PbS MONOCRYSTAL AND A STUDY OF THE MECHANISM OF ITS PHOTOELECTRIC EFFECT. L.N. Syrnev. C.R. Acad. Bulg. Sci., Vol. 13, No. 3, 269-72 (May-June, 1960). In Russian.

The surface of n-type PbS monocrystals of 1-2 ohm cm resistivity was made photosensitive by heating in sulphur vapour (several hours at 400° C) and in air (1-2 min at 590° C). The photo-e.m.f., thermoelectric power, rectifying action and the lifetime of non-equilibrium carriers were measured using a point contact. The results were similar to those obtained for sensitized PbS layers. It follows that photoconductivity in PbS layers and photo-e.m.f. at a point contact on the surface of a monocrystal are due to the same processes.

A. Tybulewicz

7674 ON THE TEMPERATURE DEPENDENCE OF THE PHOTOCONDUCTIVE DECAY TIME OF FILMS OF THE LEAD SALTS. F.M. Klaassen, J. Blok, H.C. Booy and F.J. de Hoog. Physica (Netherlands), Vol. 26, No. 8, 623-8 (Aug., 1960).

Measurements were performed on the temperature dependence of the relaxation time of PbS photodetectors. The results were compared with a theoretical expression for this time, following the kinetics of carrier transitions in semiconductors with trapping of minority carriers. Good agreement was found. From the results the value of the energy depth of the trapping centres was found to be 0.165 eV. Moreover it is concluded that the minority carriers are retrapped many times before recombination takes place.

7675 PHOTOCONDUCTIVITY OF MAGNESIUM FLUORO-GERMANATE. G. Déjardin, J. Janin and M. Dailier. C.R. Acad. Sci. (France), Vol. 252, No. 3, 400-2 (Jan. 16, 1961). In French.

The photoconductivity which is initially weak is greatly enhanced by prolonged ultraviolet irradiation. Filters were used to show that the effect is due to the shorter wavelength radiations.

J.B. Birks

7676 PHOTOCONDUCTIVITY AND TRAPPING IN SILVER CHLORIDE CRYSTALS. A.M. Gordon. Phys. Rev. (USA), Vol. 122, No. 3, 748-56 (May 1, 1961).

Photoconductivity and trapping were investigated in pure, cuprous-chloride-doped, nickel-chloride-doped, and darkened silver chloride crystals. The photoconductivity was measured primarily at 88° K. The initial photoresponse increases with rising absorption constant, peaks at wavelengths for which the absorption constant is 3 to 5 cm<sup>-1</sup>, and falls rapidly to  $\frac{1}{20}$  to  $\frac{1}{10}$  of the peak values at wavelengths at which the absorption constant is 50 to 100 cm<sup>-1</sup>. This decrease in photoresponse at short wavelengths is explained in terms of trapping and recombination through centres in a surface region. The effect of irradiation and the filling of traps was investigated. Values of the schubweg for electrons in the bulk material were obtained from these experiments. The cuprous-chloride-doped samples had a long-wavelength tail on the photo-response curve corresponding to the longwavelength tail observed in the optical absorption. The photoconductivity does not show any peaks in the infrared. There was, however, a photoresponse with a threshold at approximately 10 000 Å in samples irradiated at 88° K and a peak for those irradiated at room temperature. This response was attributed to photoemission from free silver introduced unavoidably during the preparation of the samples. The warming of samples irradiated at 88° K to fill traps produced no measurable thermoluminescence. Electrical warming curves (measurement of current as a function of time during warming) disclosed a number of trapping levels. All samples except the nickel-chloride-doped sample showed only peaks at 115°, 140°, and 180° K related to activation energies of approximately 0.20, 0.28, and 0.45 eV. The nickel-chloride-doped sample showed only peaks at 115° and 180° K. The cuprous-chloride-doped samples and the darkened pure sample showed a peak at 160° K corresponding to a thermal activation energy of ~0.36 eV. On some samples another peak was visible at 240° K with a thermal activation energy of ~0.62 eV. Possible interpretations for these various peaks are discussed.

7677 PHASES IN THE PHOTOELECTRIC SODIUM-POTASSIUM-ANTIMONY SYSTEM. W.H. McCarroll. J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 30-6 (Nov., 1960).

The phases present on the line Na<sub>3- $x$</sub> K <sub>$x$</sub> Sb (0  $\leq x \leq 3$ ) in the Na-K-Sb system were investigated by X-ray diffraction methods. The cubic compound Na<sub>2</sub>KSb, believed to be the photosensitive phase, is stable over a wide range of total composition which is consistent with the variation of Na/K ratio over which the photoelectric "multi-alkali" effect is observed. Substitution of potassium for sodium takes place up to Na<sub>1.95</sub>K<sub>0.05</sub>Sb. Solid solution of Na<sub>2</sub>Sb in hexagonal K<sub>2</sub>Sb is structurally limited to 33 mol%. The method used to prepare these samples differs markedly from the procedure used to form alkali antimonide photocathodes. However evidence is presented which indicates that the phases found in this investigation are also present in the evaporated photoelectric layers.

7678 ELECTRICALLY STIMULATED CURRENTS IN CADMIUM SULPHIDE MONOCRYSTALS ILLUMINATED WITH LIGHT. M. Borisov, S. Kynev, E. Vateva and I. Georgieva. C.R. Acad. Bulg. Sci., Vol. 13, No. 1, 23-6 (Jan.-Feb., 1960). In Russian.

Some of the energy received and stored during illumination of CdS monocrystals could be liberated by application of a voltage after

illumination ceased. The energy was liberated in the form of a current, known as electrically stimulated current. The authors describe studies of the dependence of such currents on the intensity and duration of illumination, on application of a voltage during illumination, on the intensity of applied electric fields and on temperature. The observed currents were much greater than photoconduction currents. The phenomenon could be used in  $\gamma$ -ray dosimeters, since the electrically stimulated currents were proportional to the "light dose" (intensity multiplied by duration of illumination) in a certain range of "light dose" values. A.Tybulewicz

## Thermoelectric Properties

7679 INVESTIGATION OF THE THERMO-ELECTROMOTIVE FORCE GENERATED IN A CIRCUIT [FORMED BY] DEFORMED AND UNDEFORMED REGIONS OF A METAL. G.M.Fedash and V.I.Surovova. *Fiz. Metallov i Metallovedenie* (USSR), Vol. 10, No. 1, 20-3 (July, 1960). In Russian.

The effect of various factors on thermo-e.m.f.,  $E$ , generated between deformed and undeformed Zn, was studied. In the case of polycrystalline specimens,  $E$  was negative and increased with increasing degree of deformation and decreasing initial grain size.  $E$  generated in single crystals was positive, its magnitude depending not only on the degree of deformation, but also on the relative orientation of the basal planes in the deformed and undeformed parts of the specimen. With the exception of junctions formed by two single crystals with differently oriented basal planes, junctions formed by deformed and undeformed Zn not only did not lose their ability to generate  $E$  after repeated heating, but the magnitude of  $E$  increased as a result of this treatment until a certain maximum value was reached.  $E$  was also generated between the coarsely- and finely-crystalline regions of otherwise homogeneous specimens. M.H.Sloboda

7680 CONSTRUCTION OF THERMOPILES FROM FINE WIRE. C.A.Glover and R.R.Stanley. *Analyt. Chem.* (USA), Vol. 33, No. 3, 477-8 (March, 1961).

A laboratory technique is described for making a thermopile containing 80 or more junctions. L.M.Roberts

## Dielectric Properties

7681 DIELECTRIC PROPERTIES OF POLYMERIC SYSTEMS. A.J.Curtis.

*Progress in dielectrics*, Vol. 2 (see Abstr. 5413 of 1961) p. 29-76.

A comprehensive review of investigations in which molecular interpretations are possible. The materials discussed include the polymers of ethylene, isobutylene, tetrafluoroethylene, acrylic esters, vinylacetate, vinyl ethers, styrene, vinyl acetals, vinyl chloride and chlorotrifluoroethylene, amorphous and crystalline polar polymers, crystalline polyesters and polyamides, and mixed systems, including plasticizers and dilute solutions. 133 refs. J.B.Birks

7682 THE DIELECTRIC PROPERTIES OF GLASS. P.M.Sutton.

*Progress in dielectrics*, Vol. 2 (see Abstr. 5413 of 1961) p. 113-64.

Comprehensive review. The chemical composition and structure of glasses are initially considered. The electrical properties discussed are the d.c. properties of volume and surface conductivity and dielectric absorption and polarization; the periodic-field dielectric constant and loss; and other dielectric phenomena, including breakdown strength, photoconduction and photoemission, secondary emission and bombardment effects. 115 refs. J.B.Birks

DIELECTRIC PROPERTIES OF ICE. See Abstr. 6868

7683 MECHANISMS OF DIELECTRIC ABSORPTION IN SOLIDS. R.J.Meakins.

*Progress in dielectrics*. Vol. 3 (see Abstr. 5414 of 1961), p. 151-202.

Review. Dielectric absorption mechanisms are discussed primarily in terms of reaction rate theory. Materials considered include alkali, hydrogen and deuterium halides, other ionic solids, ice and hydrates, and series of long-chain ketones, esters, ethers and alcohols and other organic compounds. The rate process parameters are tabulated. 154 refs. J.B.Birks

7684 DIELECTRIC RELAXATION IN HIGH POLYMERS. T.Tanaka.

*Suppl. Progr. theor. Phys.* (Japan), No. 10, 121-36 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The dielectric properties of high polymers at low temperatures were investigated. The following behaviour of the low-temperature absorption was confirmed: (1) the shape of the absorption curve is very broad at lower temperatures and becomes narrower at higher temperatures; (2) the apparent activation energy is very small; (3) the magnitude of low-temperature absorption is independent of the magnitude of high-temperature absorption. It is shown that these properties can be interpreted phenomenologically in terms of a generalized Fröhlich's resonance absorption mechanism.

7685 DIELECTRIC CHARACTERISTICS OF TANTALUM ANODIC FILMS AS RELATED TO FILM STRUCTURE.

D.Mohler and R.G.Hirst.

*J. Electrochem. Soc.* (USA), Vol. 108, No. 4, 347-51 (April, 1961).

The variation of these characteristics cannot be explained on the basis of bulk metal impurities alone. Very thin films on the metal surface influence the structural properties and leakage current characteristics of anodic films formed thereon. Sufficiently long exposure to hydrofluoric acid removes these films leaving clean metallic tantalum exposed and when this is anodized excellent anodic oxide films result. These anodic films are crystalline in structure (distorted  $Ta_2O_5$ ) as opposed to amorphous films previously associated with good dielectric tantalum anodic films. Electron diffraction and spectrographic data support the above views by quantitatively identifying the metallic impurities in electrolytic grade tantalum and tentatively identifying the structures of the various films on tantalum foil.

7686 SOME PROPERTIES OF PHOTODIELECTRIC LOSS AND HEAT-STIMULATED DIELECTRIC LOSS IN CRYSTAL PHOSPHORS OF THE TYPE  $ZnS:CdS:Cu:Ag$ . N.Koparanova.

*C.R. Acad. Bulg. Sci.*, Vol. 13, No. 5, 523-6 (Sept.-Oct., 1960). In Russian.

The dependence of the size and kinetics of photodielectric loss in  $ZnS:CdS:Cu:Ag$  powders on the intensity and wavelength of the exciting light and on the temperature was examined. The dependence of the heat-stimulated dielectric loss on the conditions of the previous excitation and on the heating rate was also examined. D.J.Huntley

7687 HIGH-PERMITTIVITY CERAMICS FOR CAPACITORS. K.W.Plessner and R.West.

*Progress in dielectrics*, Vol. 2 (see Abstr. 5413 of 1961) p. 165-92.

A review of the science and technology of ferroelectric ceramics with emphasis on the composition and processing factors which influence the properties of the final product. The three main sections deal respectively with the chemical composition of the ceramics in relation to their electrical properties; the chemical processes, including solid-state reactions and sintering, leading to the final ceramic; and the practical industrial techniques, some of which are peculiar to this type of ceramic. 63 refs. J.B.Birks

7688 VARIATION OF PERMITTIVITY WITH ELECTRIC FIELD IN PEROVSKITE-LIKE FERROELECTRICS. H.Diamond.

*J. appl. Phys.* (USA), Vol. 32, No. 5, 909-15 (May, 1961).

A model is considered for the case of polycrystalline ferroelectrics in which each crystallite is presumed to behave according to a free-energy function of the type formulated by Devonshire (Abstr. 7399 of 1954) for  $BaTiO_3$ . The Curie temperatures for the individual grains are taken in a Gaussian distribution about some chosen temperature. The permittivity is obtained by averaging with this distribution over all of the crystallites. In accordance with the free-energy function, it is assumed that the electric field induces a ferroelectric axis in those crystallites of the distribution which are not-ferroelectric at a given temperature. On the basis of experimental evidence,  $90^\circ$  reorientation of domains in the ferroelectric part of the distribution is presumed to be negligible for semistatic and dynamic fields. Despite the seemingly severe restriction imposed by the latter assumption, a large field sensitivity is predicted. Agreement between the theory and experimental data is excellent for both parallel and transverse fields. It is concluded that the variation of incremental permittivity is associated with an induced ferroelectric state rather than being directly a property of domain processes, and that a large variation with field must necessarily be accompanied by strong thermal sensitivity.

**7689. FERROELECTRICITY IN MIXED BISMUTH OXIDES WITH LAYER-TYPE STRUCTURES.** E.C.Subbarao. *J. chem. Phys. (USA)*, Vol. 34, No. 2, 695-6 (Feb., 1961).  
Ceramic specimens of mixed oxides with formulae  $\text{PbBi}_2\text{Nb}_2\text{O}_9$ ,  $\text{PbBi}_2\text{Ta}_2\text{O}_9$ ,  $\text{BaBi}_3\text{Ti}_2\text{NbO}_{12}$ ,  $\text{PbBi}_3\text{Ti}_2\text{NbO}_{12}$ ,  $\text{BaBi}_4\text{Ti}_4\text{O}_{15}$ ,  $\text{PbBi}_4\text{Ti}_4\text{O}_{15}$  are shown to be ferroelectric with Curie temperatures at 550, 430, 270, 290, 395 and 570°C respectively. The structures of these materials are pseudo-tetragonal, based on perovskite type layers of corner linked oxygen octahedra, joined by  $(\text{Bi}_2\text{O}_2)^{2+}$  layers, stacked along the c axis. The ferroelectric axis probably lies in the plane perpendicular to "c" and the true symmetry is probably orthorhombic. The compounds  $\text{PbDy}_2\text{Nb}_2\text{O}_9$ ,  $\text{La}_4\text{Ti}_3\text{O}_{12}$ ,  $\text{PbBi}_4\text{Zr}_4\text{O}_{15}$  could not be obtained with the layer type structure. L.E.Cross

**7690 ELECTRICAL ANOMALY AT THE CURIE TEMPERATURE FOR FERROELECTRIC SUBSTANCES.** V.G.Bhide and M.S.Multani. *J. sci. industr. Res. (India)*, Vol. 19B, No. 8, 312-13 (Aug., 1960).  
Pyrolusite and barium titanate were found to show an anomalous behaviour in respect of electrical conductivity, dielectric constant and thermoelectric power at the respective Curie temperatures.

**7691 METHOD OF TEMPERATURE CONTROL IN MICROWAVE FERROELECTRIC MEASUREMENTS.** A.L.Stanford, Jr and G.H.Thiess. *Rev. sci. Instrum.(USA)*, Vol. 31, No. 12, 1354-5 (Dec., 1960).  
The object of the method described was to avoid any temperature gradient in the sample while maintaining it at a temperature in the range 20-200°C. This was achieved by heating both the inner and outer conductors of the coaxial line in which the sample was placed for microwave measurements. K.W.Plessner

**7692 FERROELECTRICITY IN  $\text{Bi}_4\text{Ti}_3\text{O}_{12}$  AND ITS SOLID SOLUTIONS.** E.C.Subbarao. *Phys. Rev. (USA)*, Vol. 122, No. 3, 804-7 (May 1, 1961).  
On the basis of dielectric studies on polycrystalline specimens,  $\text{Bi}_4\text{Ti}_3\text{O}_{12}$  is established as a ferro-electric with a Curie temperature of 675°C. The symmetry is orthorhombic with  $a = 5.411 \text{ \AA}$ ,  $c = 32.83 \text{ \AA}$ , and  $b/a = 1.007$  at 25°C. A high-temperature X-ray study revealed a symmetry change to tetragonal at 675°C. The polar axis is probably the orthorhombic b axis.  $\text{Bi}_4\text{Ti}_3\text{O}_{12}$  is a member of oxides with the general formula  $(\text{Bi}_2\text{O}_2)^{2+}(\text{Me}_{x-1}\text{R}_x\text{O}_{3x+1})^{2-}$ . According to Aurivillius (1949-50), the crystal structure of  $\text{Bi}_4\text{Ti}_3\text{O}_{12}$  comprises a stacking of  $\text{Bi}_2\text{O}_2$  and perovskite-like  $\text{Bi}_2\text{Ti}_3\text{O}_{10}$  layers along the pseudotetragonal c axis. Multiple ion substitutions of  $(\text{Bi}^{3+}\text{Ti}^{4+})$  in  $(\text{Bi}_2\text{O}_2)^{2+}(\text{Bi}_2\text{Ti}_3\text{O}_{10})^{2-}$  by  $(\text{Me}^{2+}\text{Nb}^{5+})$  where  $\text{Me}^{2+} = \text{Ba}, \text{Pb}, \text{or Sr}$ , lead to a steep decrease of the Curie temperature.

**7693 THE THEORY OF DIELECTRIC BREAKDOWN IN SOLIDS.** R.Stratton. *Progress in dielectrics*, Vol. 3 (see Abstr. 5414 of 1961) p.233-92.  
A critical review of the theories of intrinsic dielectric breakdown. The various theories are initially described in an elementary manner in terms of the average behaviour of electrons in the conduction band; the detailed mathematical analysis is then presented in a sufficiently complete manner to permit a critical evaluation. The results are compared with the experimental data on the alkali halides. 66 refs. J.B.Birks

**7694 ON THE THEORY OF PHOTOELECTRETITES.** M.L.Chetkarov. *C.R. Acad. Bulg. Sci.*, Vol. 13, No. 4, 391-4 (July-Aug., 1960).  
The theory is based on the idea that electrons liberated photoelectrically are trapped by surface energy levels, and give rise to a long-term polarization when the field and illumination are removed. Measurements of the relaxation current flowing when the specimen is re-illuminated without an applied field are compared with predictions of the theory. K.W.Plessner

**7695 THE EFFECT OF TEMPERATURE ON PHOTOELECTRETIC STATE.** M.L.Chetkarov. *C.R. Acad. Bulg. Sci.*, Vol. 13, No. 5, 515-18 (Sept.-Oct., 1960).  
The effect on the relaxation current (see preceding abstract) of holding the specimen at an elevated temperature in the dark is calculated, and experimental data are shown. K.W.Plessner

**7696 PIEZOELECTRIC BEHAVIOR OF IMPACTED QUARTZ.** R.A.Graham. *J. appl. Phys. (USA)*, Vol. 32, No. 3, 555 (March, 1961).

This is a preliminary note on some measurements on the relation between stress and electrical charge when quartz cylinders are subjected to high impact stresses. The linear relationship

breaks down at stresses exceeding 25 kbars (1 kbar = 987 atm or 14504 lb/in<sup>2</sup>) corresponding to a charge/stress coefficient of  $2.45 \times 10^{-8}$  coulombs cm<sup>-2</sup> kbar<sup>-1</sup>. H.J.H.Starks

**THE PIEZO-OPTIC AND ELECTRO-OPTIC CONSTANTS OF ZINCBLLENDE.** See Abstr. 7702

## OPTICAL PROPERTIES OF SOLIDS

(Including X-ray Spectra)

**7697 PROPERTIES OF LITHIUM HYDRIDE. I. SINGLE CRYSTALS.** F.E.Pretzel, G.N.Rupert, C.L.Mader, E.K.Storms, G.V.Gritton and C.C.Rushing. *J. Phys. Chem. Solids (GB)*, Vol. 16, No. 1-2, 10-20 (Nov., 1960).

Single crystals of optical quality LiH were prepared by slow crystallization of the melt under hydrogen gas at moderate pressure. Measured and reported values of the physical, thermal, chemical, and optical properties of LiH and LiD are compared to those of LiF and NaCl. These properties bear out the predominantly ionic nature of crystalline LiH. The optical properties of LiH differ from those expected by a comparison with the properties of the alkali halides or the other alkali hydrides. This difference is related to distortion and polarization effects on the hydride ion in the LiH crystal lattice. There is a tendency toward covalency which may contribute to the binding energy of crystalline LiH, and this also may be responsible for its somewhat anomalous behaviour.

**7698 THE USE OF INFRARED REFLECTION SPECTRA FOR THE DETERMINATION OF THE OPTICAL CONSTANTS OF LIQUIDS IN REGIONS OF STRONG ABSORPTION.** M.Cameo. *C.R. Acad. Sci. (France)*, Vol. 252, No. 10, 1434-6 (March 6, 1961). In French.

A brief description is given of a method previously proposed [Abstr. 10745 of 1959 and C.R. Acad. Sci. (France), Vol. 248, No. 19, 2761 (May 11, 1959)] for dispersion measurements in regions containing strong absorption bands. Results are given for chloroform, carbon tetrachloride, carbon disulphide, and tetrachloroethane. W.J.Orville-Thomas

**7699 THE OPTICAL CONSTANTS OF SINGLE CRYSTALS OF HEXAGONAL SELENIUM.** V.Prosser. *Czech. J. Phys.*, Vol. 10, No. 4, 306-16 (1960).

The optical constants of single crystals of hexagonal selenium in the region of the intrinsic absorption edge in polarized light were investigated. The absorption edge for light polarized normal to the optical axis of the crystal is displaced towards longer wave-lengths. The absorption maximum of hexagonal selenium for a wavelength of 0.6  $\mu$  is interpreted as the maximum corresponding to interaction between neighbouring chains and in connection with this the position of the absorption edge of different modifications of selenium is discussed.

**7700 OPTICAL PROPERTIES AND STRUCTURE OF THIN FILMS OF SILVER.** J.P.David. *J. Phys. Radium (France)*, Vol. 21, No. 3, 157-64 (March, 1960). In French.

Describes an apparatus for the simultaneous measurement in vacuum of the reflectances R and R', transmittance T and phase change on reflection  $\phi_r$  for a thin metallic film. Experimental results dealing with the influence of the method of evaporation are given, and theoretical models of film structures proposed by different authors are examined.

**7701 INFLUENCE OF THE RATE OF FORMATION OF THIN FILMS OF SILVER, OBTAINED BY THERMAL EVAPORATION, ON THEIR TRANSMISSION AND REFLECTION FACTORS.** R.Philip. *J. Phys. Radium (France)*, Vol. 21, No. 3, 165-8 (March, 1960). In French.

Variation of the reflection and transmission coefficients with thickness is studied, for two series of thin silver films prepared at 0.5 and 50 m $\mu$  per minute. These results are compared with those recently obtained with gold films prepared at different rates of deposition.

**7702 THE PIEZO-OPTIC AND ELECTRO-OPTIC CONSTANTS OF ZINCBLLENDE.** R.Bechmann.  
J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 100-1 (Nov., 1960).  
The piezo-optic constant,  $\Pi_{44}$ , the elasto-optic constant,  $p_{44}$ , and the electro-optic constant,  $r_{41}$ , of zincblende are considered. The values for the piezo-optic constants  $\Pi_{44}$  and  $p_{44}$  given in the literature are corrected.

**7703 USE OF A TENSILE TESTING MACHINE FOR THE DETERMINATION OF STRESS AND STRAIN-OPTICAL COEFFICIENTS.** D.A.Keedy, R.J.Volungis and H.Kawai.  
Rev. sci. Instrum. (USA), Vol. 32, No. 4, 415-16 (April, 1961).  
A device which can be used in conjunction with a tensile testing machine to determine the birefringence of a polymer sample as a function of stress, strain, and temperature is described. A chamber is provided so that the sample may be held at a controlled temperature during the measurement.

**7704 INFRARED FARADAY EFFECT IN YTTRIUM GARNET.** F.Gires.  
C.R. Acad. Sci. (France), Vol. 252, No. 4, 540-1 (Jan. 23, 1961). In French.

The transmission and reflection of garnet crystals, from 0.1 to 0.3 mm thick, were measured at wavelengths between 1 and 6  $\mu$ . Faraday rotation in fields up to 2100 Oe was also measured, and used to produce a 20% infrared intensity modulation at 10 kc/s.  
L.M.Roberts

**7705 REFLECTANCE SPECTRA OF TERBIUM OXIDES IN RANGE  $Tb_2O_3$  TO  $Tb_4O_7$ .** F.Vratny.  
J. chem. Phys. (USA), Vol. 34, No. 4, 1377-9 (April, 1961).  
The diffuse reflectance spectra of terbium oxides ( $TbO_x$ ) were studied in the composition range  $1.5 \leq x \leq 1.75$  from 300 to 1500  $m\mu$ . An ultraviolet cutoff was observed at about 325  $m\mu$ . A general decrease in reflectance was observed for an increase in the oxygen to metal ratio. A band was also noted in the 380 to 400  $m\mu$  region.

**7706 COLOR MEASUREMENT OF METAL SURFACES.** J.M.Williams.  
J. Opt. Soc. Amer., Vol. 51, No. 6, 654-6 (June, 1961).  
Measurements of the optical properties of metal surfaces responsible for their colours can be made in mathematical terms by using an automatic recording spectrophotometer. A freshly prepared surface of MgO having reflectance of the order of 0.98 which varies only slightly over the whole spectrum is used as a standard, and carefully polished flat metal surfaces make up the specimen. All metals have an absorption band. This band is associated with the energy required to remove an electron from a state in the d shell to an empty state in the s shell. The wavelength of this absorption band governs the colour characteristics of metal surface.

**7707 FINE STRUCTURE IN THE ABSORPTION AND FLUORESCENCE SPECTRA OF CERTAIN PIGMENTS AT 77°K.** F.F.Litvin and R.I.Personov.  
Dokl. Akad. Nauk. SSSR, Vol. 136, No. 4, 798-800 (Feb. 1, 1961). In Russian.  
The optical properties of complex molecular substances in solution in H paraffin at 77°K were examined. A brief description of the experimental method is given. Results are shown and discussed for two phthalocyanins and protoporphyrin. In addition, fine structure was observed in the fluorescence spectrum of chlorophyll. In order to do this it was necessary to use a mixture of three paraffins at 56°. [English translation in: Soviet Physics-Doklady (USA)].  
K.N.R.Taylor

**7708 VACUUM-ULTRAVIOLET ABSORPTION STUDIES OF IRRADIATED SILICA AND QUARTZ.** C.M.Nelson and R.A.Weeks.  
J. appl. Phys. (USA), Vol. 32, No. 5, 883-6 (May, 1961).  
The optical absorption properties of  $Co^{60}$  irradiated fused silica and crystalline quartz were studied in the vacuum-ultraviolet region. The most prominent absorption band found in both materials has a maximum at 7.6 eV (1620 Å). Optical and thermal bleaching experiments indicate that this band is not necessarily complementary to a band at 5.9 eV (2100 Å), as has been assumed. Though the 7.6 eV band has approximately the same intensity in both materials for the same irradiation, the 5.9 eV band is > 20 times more intense in fused silica. The 7.6 eV band was still present after the 5.9 eV band had been thermally bleached. Additional absorption bands occur at 8.0 and 8.2 eV. Also, optical and thermal bleaching experiments suggest other absorption bands at 7.2, 7.4, 7.8, and 7.9 eV. Since

these bands (particularly the 7.6, 8.0 and 8.2 eV bands) occur in high-purity silica and quartz, it is suggested that they are associated with defects in the quartz structure and are not caused by impurities.

**7709 ABSORPTION SPECTRA OF SELENIUM AND TELLURIUM IN THE ULTRAVIOLET. INTERPRETATION OF RESULTS WITH AID OF A REDUCED ENERGY-BAND SCHEME.** S.Robin-Kandare.

J. Phys. Radium (France), Vol. 21, No. 1, 31-6 (Jan., 1960). In French.  
The transmission of thin layers of amorphous selenium and tellurium, prepared by vacuum evaporation, was measured. The spectral range studied includes a large part of the region of optical transitions (4000 to 700 Å) and internal transitions of the lowest energies (700 to 110 Å). An attempt is made to interpret the shape of the absorption curves, due to optical transitions, with the help of the reduced energy bands diagram and the data, drawn from the study of absorption discontinuities, ascribed to internal transitions.

**7710 OPTICAL STUDY OF MAGNETICALLY DILUTE CHROMIUM POTASSIUM ALUMS AT LOW TEMPERATURE.** C.Ancenot and L.Couture.  
J. Phys. Radium (France), Vol. 21, No. 1, 47-53 (Jan., 1960). In French.

Dilute chromium potassium alums (in which the  $Cr^{3+}$  ions have been substituted by  $Al^{3+}$  ions) were studied by two optical methods: observation between crossed polaroids, and absorption spectra of the  $Cr^{3+}$  ion in the red part of the visible region. All the crystals exhibit a phase transformation. The crystals separate, at low temperature, into three classes which are different as regard to their crystallographic and optical properties. These classes correspond respectively to  $n \leq 0.3$ ;  $n = 0.53$ ;  $n \geq 1.4$ , where  $n$  is the ratio of the number of  $Al^{3+}$  ions to the number of  $Cr^{3+}$  ions in the crystal. When the crystals are quenched by rapid cooling they are in a metastable state and all of them exhibit the same spectrum.

**ANALYSIS OF THE OPTICAL AND MICROWAVE SPECTRUM OF RUBY: EFFECT OF CONFIGURATION MIXING AND COVALENCY.** See Abstr. 7549

**OPTICAL ABSORPTION AND RECOMBINATION RADIATION IN SEMICONDUCTORS DUE TO TRANSITIONS BETWEEN HYDROGEN-LIKE ACCEPTOR IMPURITY LEVELS AND THE CONDUCTION BAND.** See Abstr. 7635

**MAGNETO-OPTIC EFFECTS IN THE EXCITON SPECTRUM OF CADMIUM SULPHIDE.** See Abstr. 7559

**7711 LOW-FREQUENCY SECONDARY SPECTRA OF ALKALI HALIDES.** C.Janot and A.Hadni.  
C.R. Acad. Sci. (France), Vol. 252, No. 4, 531-3 (Jan. 23, 1961). In French.

Absorption spectra in the region between 259  $\mu$  and 600  $\mu$  of nine alkali halides were obtained by means of a grating spectrometer and a pneumatic detector. A certain number of secondary maxima were recorded and although their existence was explained by the theory, a considerable disagreement between experimental and theoretical results remained.  
W.G.Jordan

**7712 DICHROISM OF 603  $cm^{-1}$  BAND OF POLYVINYL CHLORIDE.** T.Shimanouchi and M.Tasumi.  
J. chem. Phys. (USA), Vol. 34, No. 2, 687-8 (Feb., 1961).

The sense of this dichroism reverses during stretching, suggesting that the initial orientation of the chain is different from that obtained when the film is stretched to a great extent.  
G.F.Lothian

**7713 INFRARED SPECTRUM OF CRYSTALLINE BORON TRICHLORIDE.** D.A.Dows and G.Bottger.  
J. chem. Phys. (USA), Vol. 34, No. 2, 689-90 (Feb., 1961).

Spectra between 400  $cm^{-1}$  and 1000  $cm^{-1}$  have been obtained using two boron isotopes. Comparisons with previous work on  $BF_3$  point to marked differences between the two trihalides. The  $\nu_{as}$  intermolecular force constant for  $BCl_3$  (+0.0072) is consistent with a repulsive B...Cl interaction but the corresponding  $BF_3$  value is negative (-0.034) indicating a unique dipole-type interaction.  
D.L.Greenaway

**7714 INFRARED ABSORPTION OF NITRATE IONS DISSOLVED IN SOLID ALKALI HALIDES.** A.Strasheim and K.Buijs.

J. chem. Phys. (USA), Vol. 34, No. 2, 691-2 (Feb., 1961).  
The observed shifts of the asymmetrical stretching frequency ( $\nu_3$ ) for nitrate ions in solid solution are due almost entirely to repulsive (short range) forces. Samples were prepared by pressing

pellets of the nitrate form of an anion-changer (Amberlite IRA 400) with the desired alkali halide. It is shown that the activation energy of the ion exchange reaction depends on the lattice energy of the halide and not on any spatial effects.  
D.L.Greenaway

#### 7715 INFRARED SPECTRUM OF DIIMIDE.

E.J.Blau, B.F.Hochheimer and H.J.Unger.

J. chem. Phys. (USA), Vol. 34, No. 3, 1060-1 (March, 1961).

The infrared spectrum of the deposit produced and maintained at 86°K from a radio-frequency discharge through gaseous hydrazine is given. Bands which cannot be correlated with any known compound likely to be present are attributed to N<sub>2</sub>H<sub>2</sub>. Results are confirmed by mass spectrometer observations.

G.I.W.Llewelyn

#### 7716 MEASUREMENT OF ABSOLUTE INFRARED ABSORPTION INTENSITIES IN CRYSTALS.

J.L.Hollenberg and D.A.Dows.

J. chem. Phys. (USA), Vol. 34, No. 3, 1061-2 (March, 1961).

Film thickness is determined by counting interference maxima as the film is sublimed. Absolute intensities of vibration bands of benzene are about twice those found by Person and Swenson (Abstr. 13691 of 1960).

G.F.Lothian

#### STUDY OF THE HYDROXYLS IN CRYSTALLINE STRONTIUM HYDROXIDE OCTAHYDRATE BY RAMAN SCATTERING AND INFRARED ABSORPTION. See Abstr. 7717

#### 7717 STUDY OF THE HYDROXYLS IN CRYSTALLINE STRONTIUM HYDROXIDE OCTAHYDRATE BY RAMAN SCATTERING AND INFRARED ABSORPTION. E.Drouard.

C.R.Acad. Sci. (France), Vol. 252, No. 10, 1437-8 (March 6, 1961). In French.

Raman scattering experiments were made on small single crystals, and infrared absorption measurements on single crystals and powder samples. Lines and bands due to vibrations of the hydroxyl groups and water molecules were observed, and are consistent with an almost free hydroxyl radical, whose O-H bond lies along the tetragonal axis. Detailed interpretation awaits further experiment.

L.M.Roberts

#### 7718 NOTE ON THE M X-RAY EMISSION SPECTRUM OF PLUTONIUM. J.L.Bobin and J.Despres.

C.R.Acad. Sci. (France), Vol. 252, No. 9, 1302-4 (Feb. 27, 1961). In French.

The X-ray micro-analyser of Castaing was used to determine the M spectrum of plutonium in the wavelength region 2000 to 5000 X.U. The spectrometer was calibrated using a plutonium-uranium-molybdenum alloy. The wavelength of then lines was determined. Analysis of the profile of the strongest lines revealed the presence of satellite groups.

A.E.I. Research Laboratory

#### 7719 CONNECTION BETWEEN CERTAIN X-RAY AND MAGNETIC CHARACTERISTICS OF IRON-BASED ALLOYS. S.A.Nemnov and K.M.Kolobova.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 3, 466-74 (1958). In Russian.

The asymmetry of the X-ray emission lines of the transition elements is related to the electron distribution in the 3d-shell, and in particular to the magnetic moment. The paper is concerned with the relation between the dependence of the asymmetry of the K $\alpha_1$  and K $\beta_5$  lines for Fe on the concentration of Al and Zn in binary Fe-based alloys. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 3, 82-8 (1958)].

J.Thewlis

#### 7720 THE THEORY OF THE FINE STRUCTURE OF THE X-RAY ABSORPTION SPECTRUM. II. T.Shiraiwa.

J. Phys. Soc. Japan, Vol. 15, No. 2, 240-50 (Feb., 1960).

For Pt I see Abstr. 13361 of 1959. In the interpretation of the fine structure of the X-ray absorption spectrum in solids, the lifetime of the state of the electron ejected by a photon is considered. With the assumption that the inelastic cross-section of collision between the electron and an atom has a magnitude  $\sim 1A^2$ , Kronig's method for molecules is applied to solids in order to obtain the variation of the transition probability. The wave function of the final state of the transition is obtained as the sum of the plane wave, whose amplitude decreases with increasing distance from the atom which ejected the electron, and the waves scattered by the neighbouring atoms. The scattering amplitude is calculated numerically for the Hartree field of the atom. Calculations are applied to the K-absorption spectra of copper and titanium and to K-absorption

spectra of titanium in the two modifications of titanium dioxides, rutile and anatase. The calculated results agree well with experiments in copper and titanium, and the agreements become worse in titanium dioxides.

#### USE OF PrCl<sub>3</sub> IN A SOLID STATE INFRARED QUANTUM COUNTER. See Abstr. 6978

## Luminescence

#### LUMINESCENCES FROM KBr/KI SINGLE CRYSTALS.

M.Tomura and Y.Kaifu.

J. Phys. Soc. Japan, Vol. 15, No. 2, 314-21 (Feb., 1960).

Two kinds of luminescence from KBr/KI single crystals were observed. One was attributed to localized I<sup>-</sup> ions and the other to aggregated I<sup>-</sup> ions. They suffered Stokes shift and were quenched thermally at room temperature. In cases of large concentration of KI, both emissions coincided, and a new emission appeared which was coincident with that observed in pure KI crystals. The nature of the exciton in alkali halides is discussed.

#### GREEN AND BLUE EMISSION BANDS OF ZnS : Cu.

G.Curie and D.Curie.

J. Phys. Radium (France), Vol. 21, No. 2, 127-9 (Feb., 1960). In French.

It is suggested, at least as a first approximation, that the same fundamental level plays its part in both the "blue centres" and "green centres" of ZnS:Cu. The emitted light quantum depends on the excited level "associated" with the fundamental level; the transition occurs between these two states. Experimental arguments are given supporting this model, especially resulting from electroluminescence studies.

#### 7723 VARIATION OF THE DEGREE OF POLARIZATION ALONG THE FLUORESCENCE SPECTRUM OF SEVERAL DYES IN SOLID SOLUTION; EFFECT OF CONCENTRATION. E.Laffitte and C.Pujols.

C.R.Acad. Sci. (France), Vol. 252, No. 7, 1008-10 (Feb. 13, 1961). In French.

Measurements were made on solid solutions in Plexiglas of fluorescein, rhodamine B, acridine orange, tryptaflavine and acridine yellow at concentrations from 10<sup>-2</sup> to 10<sup>-5</sup> g/cm<sup>3</sup>. The degree of polarization of the fluorescence is observed to decrease with increase in the emission wavelength and with increase in concentration.

J.B.Birks

#### LUMINESCENCE OF SOME ALIPHATIC ALDEHYDES AND KETONES IN DILUTE SOLUTION CRYSTALLIZED AT 77°K. See Abstr. 6908

#### FINE STRUCTURE IN THE ABSORPTION AND FLUORESCENCE SPECTRA OF CERTAIN PIGMENTS AT 77°K. See Abstr. 7707

#### 7724 DECAY OF PHOSPHORESCENCE IN CaCO<sub>3</sub>, MgCO<sub>3</sub>, CaMg(CO<sub>3</sub>)<sub>2</sub>, and CaSO<sub>4</sub>. W.L.Medlin.

Phys. Rev. (USA), Vol. 122, No. 3, 837-42 (May 1, 1961).

The decay of phosphorescence in these solids obeys the relation  $I = I_0[b/(b + t)]^m$ , where the parameters b and m are functions of the temperature of decay and the fraction of initially filled traps (i.e., the excitation time). This result can be derived from the usual model for second-order decay, and the results predicted for the behaviour of b and m with temperature and excitation time are the same whether it is assumed that the traps and luminescent centres are independent of each other or are due to the same defect or impurity centre. It is shown, however, that in both cases the predicted behaviour is not in agreement with the experimental results for the crystals studied.

#### 7725 MICROSCOPIC OBSERVATION FOR CADMIUM SULPHIDE BOMBARDED BY 5 keV ELECTRONS.

F.Davoine, P.Pinard and M.Martineau.

J. Phys. Radium (France), Vol. 21, No. 2, 121-4 (Feb., 1960). In French.

Scanning microscopy, used to investigate cathodoluminescence of a CdS crystal, led to two important results: only some parts of the crystal are luminescent (those where concentration of primary defects is high); in the spectral region explored from (3000 to 6000 Å) emission from some of these zones is polychromatic whereas others emit one wavelength only.

7726 ABSORPTION MEASUREMENTS ON A PLASTIC SCINTILLATOR. R.J.Potter.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 286-8 (March, 1961).

The absolute absorption coefficient of a commercial plastic scintillator was measured as a function of wavelength over the region of its luminescence. The absorption coefficient was found to be quite small ( $\sim 10^{-3} \text{ cm}^{-1}$ ) through most of the visible spectrum with strong absorption beginning at about 4000 Å. The details of the experimental apparatus and the procedure are described. Some interpretations of the absorption properties are offered.

7727 SCINTILLATION RESPONSE OF ACTIVATED INORGANIC CRYSTALS TO VARIOUS CHARGED PARTICLES.

R.B.Murray and A.Meyer.

Phys. Rev. (USA), Vol. 122, No. 3, 815-26 (May 1, 1961).

Experimental studies of the response of activated ionic crystals such as NaI(Tl) and CsI(Tl) to heavy particles indicate decreasing scintillation efficiency with increasing particle mass, and a non-linearity in pulse height versus energy for heavier particles. Recent experiments indicate that the scintillation efficiency to electrons, however, is less than that to protons. In an attempt to account for these effects, this paper presents a calculation based on a model of the process of energy transfer from the incoming particle to the activator sites. In this model, the energy carriers are taken to be excitons resulting from recombination of electron-hole pairs in the wake of the particle. The migration of carriers to activator sites is described by a one-velocity diffusion equation in which the density of unoccupied activator sites,  $N_a$ , is a function of space and time. The diffusion equation is coupled with a second differential equation describing the time dependence of  $N_a$ . The solution to these equations indicates that the depletion of available activator sites by a particle with high  $dE/dx$  can account for observed saturation effects. This model further contains the activator concentration as a parameter, and permits a prediction of scintillation efficiency as a function of both  $dE/dx$  and concentration. The low scintillation efficiency to electrons is predicted as a consequence of the smaller recombination probability for particles of very low  $dE/dx$ . Finally, for a low- $dE/dx$  particle in a crystal of 0.1 mole% activator concentration the diffusion length of energy carriers is found to be of order 20 Å.

RADIATION OF PLASMA OSCILLATIONS IN THIN SILVER FILMS. See Abstr. 7568

7728 THE EFFECT OF TEMPERATURE ON FIELD INTENSIFICATION AND FIELD QUENCHING OF CATHODOLUMINESCENCE.

H.Gobrecht, H.E.Gumlich and J.zum Bruch.

Z. Phys. (Germany), Vol. 162, No. 2, 169-79 (1961). In German.

ZnS:Mn was investigated. It was found that the cathodoluminescence is profoundly influenced by alternating electric fields. At room temperature, the emission due to the manganese is enhanced, and that due to self-activation is quenched by the field. At lower temperatures, however, the direction of the energy transport controlled by the electric field changes the sign: the emission of manganese is quenched by the field, whereas the luminescence due to self-activation is enhanced. This behaviour may be explained with reference to a model according to which the electrons gain energy in the electric field and the number of occupied states changes.

7729 ELECTROLUMINESCENCE IN ZINC SULFIDE SINGLE CRYSTALS. S.Narita.

J. Phys. Soc. Japan, Vol. 15, No. 1, 128-36 (Jan., 1960).

By using the vapour-phase synthesis method, zinc sulphide single crystals were grown of pure zinc and bomb hydrogen sulphide. They were doped with two impurities: copper and chlorine. The electroluminescence brightness waves in these crystals were studied by applying rectangular pulse voltages. Since "in-phase" electroluminescence was dominant in the crystals lacking chlorine and having appreciable voltage-dependency, it was concluded that it occurred as a result of electron injection from the cathode. In order to find the mechanism of the "out-of-phase" electroluminescence, infrared quenching was used. ZnS:Cl:Cu was a typical case sensitive to quenching, and an artificial junction (ZnS:Cl-ZnS:Cu) was a typical case insensitive to quenching. It was supposed that the difference between these two cases resulted from the difference in the mechanism of supply of the primary electrons of electroluminescence.

7730 DIRECT CURRENT ELECTROLUMINESCENCE AT LOW VOLTAGES. W.A.Thornton.

Phys. Rev. (USA), Vol. 122, No. 1, 58-9 (April 1, 1961).

Electroluminescence due to d.c. excitation occurs in activated ZnS films at 2.0 V. Since in the d.c. case no ambiguity is introduced by possible transient potential differences within the phosphor layer these experiments show that electroluminescence can occur at applied voltages corresponding to about half the band gap (3.8 eV) of the ZnS phosphor. The acceleration-collision theory of electroluminescence is thus ruled out at low voltage, and since no appreciable difference is found to be characteristic of the electroluminescence at low voltages, the acceleration-collision mechanism may not be important in any voltage range.

7731 LUMINESCENCE DURING ANNEALING AND PHASE CHANGE IN CRYSTALS. N.M.Johnson and F.Daniels.

J. chem. Phys. (USA), Vol. 34, No. 4, 1434-9 (April, 1961).

The accepted definition of thermoluminescence is the thermal release of trapped electrons with accompanying optical transitions. This interpretation presupposes an exposure to ionizing radiation in order to fill the electron traps. Other processes such as mechanical stress and chemical reaction can also serve to excite electrons as observed in triboluminescence and chemiluminescence. It is proposed that some instances of luminescence during heating are produced by physical processes other than the release of previously trapped electrons. Evidence for this is provided by the correlation of certain glow-curve peaks with crystalline annealing, decomposition, and polymorphic transition. Measurements of annealing and polymorphic changes were made through X-ray diffraction. Attention to interpret the thermal or radiation history of geological specimens by thermoluminescence must account for both radiation-induced and radiation-independent forms of light generation.

7732 THERMOLUMINESCENCE OF ZINC SULFIDE PHOSPHORS. K.Osada.

J. Phys. Soc. Japan, Vol. 15, No. 1, 145-9 (Jan., 1960).

The thermoluminescence glow curves of some zinc sulphide phosphors were obtained for two different exponential heating rates by means of an oscilloscope. The values of the depth and frequency factor of traps were obtained by the Booth method. The frequency factor was not constant for all traps, but became larger as the depth increased. Equations are also developed which permit analysis of the glow curves for the exponential heating rate.

## MAGNETIC PROPERTIES OF SOLIDS

7733 MAGNETIC PHASE TRANSITIONS OF COBALT CHLORIDE. W. van der Lugt and N.J.Poulis.

Physica (Netherlands), Vol. 26, No. 11, 917-21 (Nov., 1960).

In single crystals of  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$  the Néel temperature was determined as a function of the external magnetic field. The external magnetic field was varied from 0-10 000 Oe and was directed along the preferred axis and along a direction perpendicular to it. The threshold field was determined as a function of the temperature in the temperature range from 1.0°K up to the Néel point. The spontaneous magnetization was measured as a function of temperature in zero external field from 1°K up to 0.1°K below the Néel temperature.

7734 PARAMAGNETIC BEHAVIOR OF METALLIC CERIU AND EUROPIUM.

R.V.Colvin, S.Arajs and J.M.Peck.

Phys. Rev. (USA), Vol. 122, No. 1, 14-18 (April 1, 1961).

The magnetic behaviour of metallic polycrystalline Ce and Eu was studied above room temperatures. The measured paramagnetic behaviour of cerium can be explained using the interacting  $\text{Ce}^{3+}$  ion model ( $\theta = -50^\circ\text{K}$ ) and the Van Vleck theory of paramagnetism with an additional temperature-independent paramagnetic term  $\chi_c = 1.00 \times 10^{-6} \text{ g}^{-1} \text{ cm}^3$  resulting from the conduction electrons. Europium metal has an unusual magnetic behaviour. Its paramagnetic properties in the solid state cannot be explained on the basis of the noninteracting  $\text{Eu}^{2+}$  model. Near the melting point metallic europium behaves as a collection of weakly interacting  $\text{Eu}^+$  ions. The Bohr magneton number of liquid europium is very close to that of  $\text{Eu}^{2+}$  ions. [For work on other rare-earth metals, see Abstr. 8030, 11810, 18169 of 1960].

7735 ANOMALIES IN THE MAGNETIC SUSCEPTIBILITY AND ELECTRICAL RESISTIVITY OF VANADIUM.

J.P.Burger and M.A.Taylor.

Phys. Rev. Letters (USA), Vol. 6, No. 4, 185-7 (Feb. 15, 1961).

Reports an anomaly in the temperature dependence of the magnetic susceptibility at 245°K and its association with a resistance anomaly in the same sample at about the same temperature.

M.G.Priestley

7736 PROCEEDINGS OF THE MEETING OF THE FERRO-MAGNETISM WORKING PARTY IN WIESBADEN FROM 7 TO 19 OCTOBER 1960.

Z. angew. Phys. (Germany), Vol. 13, No. 3, 121-68 (March); No. 4, 169-93 (April, 1961). In German.

Thirty-two papers were presented, abstracts of which will appear in "Physics Abstracts". See also Abstr. 18171 of 1960.

7737 STATISTICAL MECHANICS OF FERROMAGNETISM; SPHERICAL MODEL AS HIGH-DENSITY LIMIT.

R.Brout.

Phys. Rev. (USA), Vol. 122, No. 2, 469-74 (April 15, 1961).

It is shown that there is a class of graphs of the Ising model (or Heisenberg model for  $T > T_{\text{Curie}}$ ) which is comprised of cycle graphs plus some excluded volume effects which sum to the spherical model. The spherical model, suitably generalized for  $T < T_{\text{Curie}}$ , was conjectured in a previous work (Abstr. 18172 of 1960) to be the high-density limit of the Ising model, correct to  $1/z$ , where  $z$  is the number of spins in the range of the exchange potential (not restricted to nearest neighbour interactions).  $z^{1/3}$  measures the range of the exchange potential. This is now proved by examining the omitted graphs. The error is shown to be  $O(1/z^2)$ .

7738 ON THE NATURE OF THE MAGNETIC COUPLINGS IN TRANSITIONAL METALS.

J.Friedel, G.Leman and S.Olszewski.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 325S-330S (March, 1961).

This paper suggests a simple model of magnetism for transitional metals which is somewhat intermediate between Heisenberg's atomic model and Stoner's band model. Starting with a paramagnetic band, described in the tight-binding approximation and with equal population of both spin directions, exchange interactions are introduced. They are shown able to produce localized magnetic moments by attracting locally the (travelling) electrons of one spin direction at the expense of the others. A simple condition is obtained for such magnetic moments to appear spontaneously; it is shown to be fulfilled in many transitional metals. With the use of general results obtained recently by the authors and by others, it is then shown that each of these magnetic moments, if produced alone, should extend over a certain region in space, and should be surrounded by "fringes" of spin polarization with an alternating sign. The size of the central region and the wavelength of the fringes are related to the average wavelength of the Fermi electrons, and thus to the filling of the d band. The sign and the strength of the coupling between magnetic moments centred on neighbouring atoms is deduced from the extent of their overlap. The magnetic couplings observed in the first transitional series are shown to be in fair agreement with this model. The conditions prevailing in the other series and in alloys are also discussed. This model is compared to those put forward by Zener, Yoshida, and Slater. It is emphasized that it leads to the equivalent of chemical exchange integrals between the moments of neighbouring atoms without losing the characteristic features of the d band, especially its high electronic specific heat and Pauli paramagnetism.

7739 SPIN WAVES IN FERROMAGNETS AND ANTIFERROMAGNETS. I.

A.I.Akhiezer, V.G.Bar'yakhtar and M.I.Kaganov.

Uspekhi fiz. Nauk (USSR), Vol. 71, No. 4, 533-79 (Aug., 1960). In Russian.

A review of the following topics: phenomenological theory of spin waves in ferromagnetics; quantization; high-frequency properties and ferromagnetic resonance; surface impedance; coupled magnetoelastic waves; energy spectrum of antiferromagnetics; thermal and magnetic properties. 55 references. [English translation in: Soviet Physics—Uspekhi (USA), Vol. 3, No. 4, 567-92 (Jan.-Feb., 1961)].

E.P.Wohlfarth

7740 THE THEORY OF THE FERROMAGNETISM OF NICKEL-COPPER ALLOYS. J.Seiden.

C.R. Acad. Sci. (France), Vol. 252, No. 2, 249-51 (Jan. 9, 1961). In French.

The previously developed stochastic theory (Abstr. 2468, 3890 of 1961) is applied to Ni-Cu alloys. A satisfactory explanation can be given for Cu concentrations less than 30%.

D.J.Oliver

7741 A MODEL FOR SUPEREXCHANGE INTERACTION IN MAGNETIC COMPOUNDS WITH ZINCBLENDE STRUCTURE. K.P.Sinha and S.Koide.

Sci. Pap. Coll. Gen. Educ. Univ. Tokyo (Japan), Vol. 10, No. 2, 195-205 (Dec., 1960).

A model for the superexchange interaction mechanism in zincblende-type magnetic compounds is proposed. The ideas of an earlier paper (Abstr. 21058 of 1960) are applied to such systems. The elementary unit chosen is  $M_4X$  with cations at the corners of a regular tetrahedron and an anion at the centre. It is shown that the antiferromagnetic (singlet) state is more stable than the ferromagnetic states. A quantitative estimate for the  $Mn_4S$  unit yields reasonable results.

7742 EXCHANGE ANISOTROPY IN ALLOYS OF COMPOSITION  $(Ni,Fe)_3Mn$ . J.S.Kouvel.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 152-7 (Nov., 1960).

Disordered face-centred cubic alloys in which the nickel in the composition  $Ni_3Mn$  is partially replaced by iron were studied magnetically over a wide temperature range (4.2-750°K). When cooled to 4.2°K in a magnetic field the alloys of <50 at.% Fe exhibit hysteresis loops that are displaced from their symmetrical positions about the origin, as previously reported for the  $Ni_3Mn$ . At higher iron concentrations this exchange anisotropy behaviour disappears, and the temperature and field dependences of magnetization become those characteristic of a simple antiferromagnet. This information together with paramagnetic susceptibility data suggest that while the Fe-Ni exchange coupling is strongly ferromagnetic both the Fe-Mn and Fe-Fe interactions are antiferromagnetic in this alloy system.

7743 THE MAGNETIC PROPERTIES OF  $Fe_2P$ . M.C.Cadeville and A.J.P.Meyer.

C.R. Acad. Sci. (France), Vol. 252, No. 8, 1124-6 (Feb. 20, 1961). In French.

The magnetic properties of  $Fe_2P$ , pure and containing 0.2% excess of phosphorus, were measured. The Curie temperature of  $Fe_2P$  is -7°C, the saturation moment is 1.32  $\mu_B$  per atom of iron.  $Fe_2P$  is magnetically hard and  $Fe_2P + 0.2\% P$  extremely so. For the former material  $K_1 = 8.2 \times 10^6$  ergs/cm<sup>3</sup> at 20°K and  $7.3 \times 10^6$  ergs/cm<sup>3</sup> at 110°K. For the latter material the maximum field obtainable, 24 000 Oe, was insufficient to saturate the material. The saturation moment and Curie temperature of both materials are however the same. Similarly, above the Curie temperature both materials show the same behaviour. Up to 980°C, a Curie-Weiss law is followed with  $\theta_p = 165^\circ\text{C}$  and  $C_M = 1.97$ .

S.A.Ahern

INFLUENCE OF HEAT TREATMENT ON THE CURIE POINT OF THE ALLOY ELINVAR. See Abstr. 7812

7744 EXCHANGE ANISOTROPY IN COBALT-MANGANESE ALLOYS. J.S.Kouvel.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 107-14 (Nov., 1960).

Magnetization measurements between 4.2° and 750°K on Co-Mn alloys of about 25, 30 and 35 at.% Mn indicate that no simple disappearance of ferromagnetism takes place with increasing Mn concentration, although the magnetic properties of these alloys are very sensitively dependent on composition. When cooled to 4.2°K in a magnetic field, all these alloys exhibit hysteresis loops that are asymmetrical with respect to the origin. This behaviour, similar to that recently reported for Ni-Mn alloys, is believed to arise in this case also from exchange anisotropy interactions between regions of ferromagnetic and antiferromagnetic spin alignment. From the high temperature paramagnetic susceptibilities of these Co-Mn compositions and of disordered Ni-Mn alloys of 20 to 35 at.% Mn, it is concluded that an increasing number of atomic moments are antiferromagnetically aligned with increasing Mn concentration in both alloy systems. It is shown that this result combined with the statistical composition fluctuations inherent to a disordered alloy provides a plausible model for the exchange anisotropy in these materials.

7745 DIRECTIONAL ORDER PRODUCED BY TENSION IN A 50-50 Ni-Co ALLOY. R. Vergne. C.R. Acad. Sci. (France), Vol. 252, No. 1, 82-4 (Jan. 4, 1961). In French.

Néel has shown that the anisotropy energy produced by an applied stress in a binary ferromagnetic alloy is zero if the alloy obeys Vegard's law. The results obtained with 50-50 Ni-Co contradict this. Details of the experiments are given. D.J. Oliver

7746 STUDIES ON THE MAGNETIC ANISOTROPY INDUCED BY COLD ROLLING OF FERROMAGNETIC CRYSTAL. II. IRON-ALUMINUM ALLOYS. S. Chikazumi, K. Suzuki and H. Iwata. J. Phys. Soc. Japan, Vol. 15, No. 2, 250-60 (Feb., 1960).

For Pt I see Abstr. 8293 of 1959. The magnetic anisotropy was measured of several single crystals of Fe<sub>3</sub>Al which were rolled in definite crystallographic directions. Rolling on (110) and parallel to [001] induced the uniaxial anisotropy as large as  $7.1 \times 10^5$  erg cm<sup>-3</sup> at only 12% reduction. The direction of easy magnetization in this case was parallel to roll direction, which was also confirmed by the observation of domain pattern. (110)[110], (001)[010] and (001)[110] rolling were also investigated. Calculations were made on the roll magnetic anisotropy in terms of the "slip-induced directional order", on the assumption of a {110}<111> slip system. It was found that dipole-dipole interaction between second nearest neighbours must be taken into consideration in order to explain the experimental facts.

7747 FIRST MAGNETOCRYSTALLINE ANISOTROPY CONSTANTS OF SOME IRON-SILICON ALLOYS. S. Arajs, H. Chessin and D. S. Miller. J. appl. Phys. (USA), Vol. 32, No. 5, 857-9 (May, 1961).

First magnetocrystalline anisotropy constants  $K_{100}$  of 3.6, 6.7, 8.8, and 12.4 wt% Si-Fe alloys were measured at 77°K and 297°K by determining the torque exerted on {100} single-crystal disks in uniform magnetic fields. The following results on disordered alloys were obtained:

| Composition (wt% Si) | Temperature (°K) | $K_{100} \times 10^3$ (erg cm <sup>-3</sup> ) |
|----------------------|------------------|---|
| 3.6                  | 77               | 430 ± 10                                      |
| 3.6                  | 297              | 360 ± 10                                      |
| 6.7                  | 77               | 290 ± 10                                      |
| 6.7                  | 297              | 205 ± 10                                      |
| 8.8                  | 77               | 245 ± 10                                      |
| 8.8                  | 297              | 165 ± 10                                      |
| 12.4                 | 77               | 120 ± 5                                       |
| 12.4                 | 297              | 78 ± 5  |

The measurements of this investigation are compared with the previously known studies. The agreement, where an overlap occurs, is satisfactory.

7748 STUDY OF THE ADDITION OF THERMAL-FLUCTUATIONS AFTER-EFFECT AND CREEPING ["REPTATION"]. J.C. Barbier. C.R. Acad. Sci. (France), Vol. 252, No. 1, 79-81 (Jan., 1961). In French.

7749 THE INFLUENCE OF SUCCESSIVE ASYMMETRICAL MAGNETIZATION REVERSAL ON THE MAGNETIC STATE OF OPEN SAMPLES. V. Hajko and J. Daniel-Szabó. Czech. J. Phys., Vol. 10, No. 4, 294-8 (1960).

The successive asymmetrical reversals, where the macroscopic demagnetization field has a significant effect during magnetization reversal, lead to a sort of rotation of the asymmetrical loops performed one after another. This effect is similar to "reptation", which was studied experimentally by Nguyen van Dang and theoretically explained by Néel. The quantitative expression of the rotation of asymmetrical loops in open samples as a function of the number of loops and amplitude of the disymmetry is similar to that with the "reptation" effect.

7750 SOME MAGNETIC PROPERTIES OF MANGANESE-BISMUTH ALLOY POWDER. G.S. Kandaurova and Ya.S. Shur. Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 37-41 (July, 1960). In Russian.

Magnetization curves are constructed for isotropic MnBi powders demagnetized by three different methods, and the effect of the method employed and the screen analysis of the powder on its magnetic properties is studied. The anomalous behaviour of very

fine powders, similar to that of magnetically anisotropic pseudo-monocrystalline powder specimens, is attributed to the specific magnetic structure of very fine particles, postulated to be transitional between the multi-domain and single-domain types of structure. M.H. Slobod

7751 AN IMPROVED MODEL FOR FLUX REVERSAL IN Ni-Fe CORES. I. Leliakov and F.J. Friedlaender. Special technical Conference on nonlinear magnetics and magnetic amplifiers, p. 146-55. New York: American Institute of Electrical Engineers (Oct., 1960). [Publication T-121].

Discusses applied field intensities in the range  $H_c < H < 100 H_c$ . Flux reversal in tape cores occurs primarily through domain wall motion, i.e. the growth of magnetic domains aligned with the field at the expense of unaligned domains. Hence in order to describe the dynamic core behaviour during flux reversal, it is sufficient to determine the rate of motion and general geometry of domain walls. Only irreversible flux changes are considered, i.e. no wall motion assumed to exist after removal of the applied field. The model developed allows the prediction of instantaneous flux variation in initially saturated cores over a wide range of field intensities and thus represents an improvement over previously proposed models of limited applicability. The model is also directly applicable to the description of core behaviour of initially unsaturated cores as well as to the analysis of flux reversal at low fields. In the latter case the model needs to be extended to include the domain wall geometries produced by very small numbers of participating domains. S.C. Dunn

7752 STATISTICAL DYNAMICS OF BOUNDARY MOTION. R. Kikuchi. Ann. Phys. (USA), Vol. 11, No. 3, 328-37 (Nov., 1960).

Motion of a domain wall between two magnetic domains of the Ising model induced by an external magnetic field is investigated by means of the technique of statistical dynamics developed by the author. It is assumed that each magnetic spin has a finite kinetic probability for changing its sign per unit time and that the spin system is in thermal contact with a heat bath. The path probability  $G$  for the change of state of the system for a short time interval is written in terms of a set of path parameters using the point approximation (the Bragg-Williams approximation) of the cluster-variation method, and then  $G$  is maximized with respect to the path parameters to determine the most probable change of state. When the profile of the domain wall is smooth, it is approximated by a continuous function of the distance; the change of the profile is then written as a differential equation. In the steady state when the domain wall is displaced parallel to itself, the differential equation takes the form of an eigenvalue equation with the velocity of the wall  $v$  playing the role of the eigenvalue. This eigenvalue equation is nonlinear, but it can be linearized when the applied magnetic field is weak and  $v$  is small. The equation for this case is solved and  $v$  is expressed in terms of known quantities. The technique developed in this paper is applicable to more realistic models of domain boundaries and also can be combined with better approximations of the cluster-variation method.

7753 THE POLARITY OF DOMAIN WALLS IN THIN FERROMAGNETIC FILMS. L.V. Kirenskii and V.A. Buravikhin. Dokl. Akad. Nauk SSSR, Vol. 136, No. 3, 575-6 (Jan. 21, 1961). In Russian.

The double domain walls in thin films are observed to be formed of two adjacent Bloch walls of opposite sign. Ordinary Bloch walls in thin films are found to be of alternate polarity. [English translation in: Soviet Physics-Doklady (USA)]. M.G. Priestley

7754 THE MAGNETIC DOMAIN STRUCTURE OF THIN MONOCRYSTALLINE LAYERS OF IRON. D. Unangst. Ann. Phys. (Germany), Vol. 7, No. 5-6, 280-301 (1961). In German.

The article describes an experimental study of the domain structure in single iron crystals with thicknesses between 55 Å to 10000 Å by the Bitter figure technique. In the thicker crystals the domain structure corresponds to that of the bulk material, but as the thickness is progressively reduced, 180° boundaries become energetically less favourable and in 800 Å and thinner crystals most of the remaining walls are of the 90° type. Remagnetization in such a case occurs by rotation of magnetization vectors which becomes reversible in the thinnest layers. The variation of coercivity with sample thickness could be estimated. Anomalous wall directions in the thinnest layers can be interpreted in terms of Néel's assumption that the magnetization vectors must remain in the plane of the specimen. R. Parkes

COERCIVE FORCE OF NICKEL FILMS. See Abstr. 7619

**7755 ANNEALING OF OBLIQUE-INCIDENCE PERMALLOY FILMS.** G.P.Weiss and D.O.Smith.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 85S-86S (March, 1961).  
The anisotropy of evaporated Permalloy films (composition near zero magnetostriction) deposited on glass at  $45^\circ$  to the substrate normal and at a substrate temperature of  $200^\circ\text{C}$  was studied after anneal for several hours at  $300^\circ\text{C}$ . After anneal the room temperature easy-axis of films with positive magnetostriction is in the original direction. However, films with negative magnetostriction develop a new room temperature easy-axis  $90^\circ$  to the original one; at  $300^\circ\text{C}$  the easy-axis is in the original direction. Application of a large magnetic field in any direction during anneal does not influence the final magnetic anisotropy in either case. These effects are qualitatively explained by assuming the anneal to increase the tension along the long axis of oblique-incidence chains, a process which converts surface energy into strain energy. Anisotropy was measured by resonance in a coaxial bridge over the frequency range 50 to 2100 Mc/s. A rectangular coaxial cavity is used which can be heated to  $500^\circ\text{C}$  in a vacuum of  $10^{-6}$  mm Hg; continuous angular orientation of the film is possible with a resolution of  $\pm 0.5^\circ$ . Bridge balance is good enough to permit samples of less than 100 Å thickness to be measured.

**7756 ANISOTROPY IN PERMALLOY FILMS EVAPORATED AT GRAZING INCIDENCE.** M.S.Cohen.

J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 87S-88S (March, 1961).  
The magnetic and optical anisotropies observed in oblique-incidence Permalloy film show anomalous behaviour for incidence angles greater than  $60^\circ$  (grazing incidence). In particular, the easy axis and the direction of greatest optical absorption are parallel to the vapour beam for incidence angles greater than about  $70^\circ$ , while they are perpendicular to this direction for smaller angles. The anomalies for grazing-incidence films are caused by a shape anisotropy differing from that previously found in lower angle oblique-incidence films. This new shape anisotropy is attributed to the elongation in the beam direction of the particles composing the crystallite chains which are found in all oblique-incidence films; such shape anisotropy was directly observed by electron microscopy.

**7757 THERMAL FLUCTUATION EFFECTS IN THIN MAGNETIC FILMS.** E.P.Wohlfarth.

J. Electronics and Control (GB), Vol. 10, No. 1, 33-7 (Jan., 1961).  
The observation (Abstr. 1230 of 1960) that the coercive force of thin films is time dependent is interpreted quantitatively on the basis of the theory of thermal fluctuation effects, and values of the anisotropy field and mean effective crystallite size are deduced and discussed.

**7758 UNIFORM AND NON-UNIFORM FORM EFFECT IN MAGNETOSTRICTION.** R.Gersdorf.

Physica (Netherlands), Vol. 26, No. 8, 553-74 (Aug., 1960).  
A calculation is made of the form effect observed in magnetostriction. On the assumption that the strains are uniform, a calculation of this effect is made for ellipsoids of rotational symmetry magnetized along a principal axis. This is done for elastically isotropic material and for an elastically anisotropic cubic crystal, with the cube axes in an arbitrary direction. A more accurate investigation showed, however, that in most cases the strains are far from uniform. An exact calculation of the strains as a function of the position could only be made for a sphere, an isotropic sphere and a monocrystalline sphere of cubic crystal symmetry, the magnetization being in a (110) plane. An approximate calculation is made for a few other cases that may be of importance for experiments in which magnetostriction constants are determined.

**7759 MEASUREMENTS OF THE NON-UNIFORM FORM EFFECT IN MAGNETOSTRICTION.**

R.Gersdorf, J.H.M.Stoelinga and G.W.Rathenau.  
Physica (Netherlands), Vol. 27, No. 4, 381-4 (April, 1961).  
A procedure is indicated for high-accuracy measurements of the five magnetostriction constants making use of the strain gauge technique. Measurements were made in three different places of a sphere and on disks of different thickness to diameter ratio, made from a single crystal of an iron alloy containing 5.6 wt% silicon. In this case the form effect has the same order of magnitude as the magnetostriction; the results are in fair agreement with calculations of the non-uniform form effect given in the preceding abstract.

**7760 MAGNETOSTRICTION AND MAGNETIZATION OF TERNARY IRON-NICKEL-COBALT SYSTEMS OF IRON-NICKEL BASE AND IRON-COBALT BASE ALLOYS.**

S.I.Voskoboynikov.  
Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1011-16 (1958). In Russian. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 51-6 (1958)].

**ENERGY THEOREM IN MAGNETO-ELASTICITY.**  
See Abstr. 7526

**7761 FERROMAGNETIC RELAXATION. I. THEORY OF THE RELAXATION OF THE UNIFORM PRECESSION AND THE DEGENERATE SPECTRUM IN INSULATORS AT LOW TEMPERATURES.** M.Sparks, R.Loudon and C.Kittel.

Phys. Rev. (USA), Vol. 122, No. 3, 791-803 (May 1, 1961).  
A scheme is proposed for the relaxation processes at low temperatures accompanying excitation of uniform precession spin waves in a ferromagnetic resonance experiment, with particular reference to highly pure yttrium iron garnet. The processes are: (1) scattering of uniform precession spin waves into the degenerate spin-wave modes by polishing imperfections on the sample surface; (2) equalization of the populations of the degenerate spin-wave modes, also by surface imperfections; and (3) relaxation of the degenerate modes by Raman scattering of thermal spin waves through the magnetic dipole interaction. Relaxation times for the three processes are calculated and compared with experimental values, with reasonable agreement.

**7762 BEHAVIOR OF MAGNETIC MATERIALS UNDER EXTREME ENVIRONMENTAL CONDITIONS.**

Special technical Conference on nonlinear magnetics and magnetic amplifiers, 141-7. American Institute of Electrical Engineers (Oct., 1960). [Publ. T121].

The environmental conditions considered are temperature, pressure, radiation and atmosphere. As far as temperature is concerned there is obviously a temperature above which the ferromagnetic properties completely disappear. It is concluded that, generally speaking, those materials which survive best at high temperatures are those which are, however, less desirable for moderate temperature applications. Uni-directional pressure effects are well known to be harmful. Omni-directional stresses, however, are found to be relatively harmless to the magnetic properties. Prolonged radiation, as in the immediate proximity of a reactor, affects magnetic properties much the same as prolonged heating. Those materials which owe their distinctive properties to special heat treatments are most rapidly and permanently affected by high-energy radiations. Materials such as ferrites, which have low Curie temperatures, are impaired magnetically if their temperature rises excessively either due to proximity to heat source or to internal conversion of radiant energy into heat. Otherwise ferrites are notably immune to radiation damage by either temporary or long-term exposure. Atmospheric effects were worst at high temperatures and under oxidizing conditions. Cores made of supermendur exhibited anomalous transient defects when tested in air at  $500^\circ\text{C}$  and upon return to room temperature the cores exhibited permanent magnetic degradation. The results reported on a number of materials are tabulated.

S.C.Dunn

**7763 PARTICLE INTERACTION IN MAGNETIC RECORDING TAPES.** J.G.Woodward and E.Della Torre.

J. appl. Phys. (USA), Vol. 32, No. 1, 126-7 (Jan., 1961).  
A continuation of previous work (Abstr. 1792 of 1960); the Preisach distribution function is obtained by finite difference methods from anhysteretic magnetization measurements.

E.P.Wohlfarth

**MEASUREMENT OF PERMEABILITY TENSOR OF FERRITES AT 3000 AND 8500 Mc/s.** See Abstr. 7116

**7764 THE ANHYSTERETIC MAGNETIZATION CURVES OF FERRITES WITH DIFFERENT HYSTERESIS LOOPS.**

M.Kornetzki and E.Rösz.  
Z. angew. Phys. (Germany), Vol. 13, No. 1, 28-31 (Jan., 1961). In German.

The anhysteretic magnetization curve is deduced from a Preisach diagram and compared with the initial magnetization curve. The properties of the anhysteretic magnetization curves for ferrites with normal, rectangular, Isoperm and Perninvar type hysteresis loops are discussed with the aid of Preisach diagrams.

A.J.Manuel

7765 THE CALCULATION OF THE TEMPERATURE AND FIELD DEPENDENCES OF THE MAGNETIZATION OF MAGNETIC-UNIAXIAL FERRITES. E.N. Yakovlev. Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 976-83 (1958). In Russian.

The anisotropy of the magnetic properties of magnetic-uni-axial ferrites is considered as a consequence of the anisotropy of the "tensor of exchange reaction". Using the method of the approximate secondary quantum, a calculation is made of the field dependence of the magnetization, and also of the hysteresis loop in the magnetic reversal of a monocrystal at  $T = 0^\circ \text{K}$ . A calculation is made of the temperature dependence of the magnetization along the anisotropy axis and perpendicular to it in a region of temperatures close to absolute zero. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 16-23 (1958)].

7766 THE STATISTICS OF SUPEREXCHANGE INTERACTION AND IONIC DISTRIBUTION IN SUBSTITUTED FERRI-MAGNETIC RARE EARTH IRON GARNETS. S.Geller. J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 21-9 (Nov., 1960).

Ideas on the statistics of superexchange interaction developed and applied to substituted yttrium-iron garnets by Gilleo (Abstr. 11897 of 1960) are extended and applied to substituted rare earth iron garnets. It is shown by means of structural considerations that only four interactions per c site ion with d site ions are important in determining the contribution of the c site ions to the  $0^\circ \text{K}$  saturation magnetization. The statistical theory accounts especially well for the behaviour of  $n_B(0^\circ \text{K})$  versus  $x = (y + z)$  of the system  $\text{Gd}_3 \text{Al}_y \text{Fe}_{2-y} (\text{Al}_2 \text{Fe}_{3-x}) \text{O}_{12}$  and for  $\text{Gd}_2.4 \text{Ca}_{0.6} \text{Al}_y \text{Fe}_{2-y} \{ \text{Gd}_3 [\text{Al}_y \text{Fe}_{2-y}] (\text{Al}_2 \text{Fe}_{3-z}) \text{O}_{12}$  and for



corrects the previously obtained ionic distribution which had been considered anomalous. Other systems are also considered. Crystal chemical aspects of some of the results, compensation points and some minor limitations of the treatment are discussed.

7767 MANGANESE ZINC FERRITES WITH DIFFERENT KINDS OF MAGNETISATION LOOPS.

M.Kornetzki, E.Moser and E.Rösler. Z. angew. Phys. (Germany), Vol. 13, No. 1, 31-6 (Jan., 1961). In German.

Five specimens containing between 51 and 58 mol.% oxygen show all known forms of hysteresis loops: rectangular, normal, isoperm and perminvar. The magnetic properties of the isoperm material have been studied more extensively. Below  $-80^\circ \text{C}$ , the hysteresis loops become rectangular, above  $100^\circ \text{C}$  they become normal. The origin of the isoperm loops is discussed with reference to this and other work.

A.J.Manuel

7768 EXCHANGE ANISOTROPY IN MIXED MANGANITES WITH THE HAUSMANNITE STRUCTURE.

I.S.Jacobs and J.S.Kouvel. Phys. Rev. (USA), Vol. 122, No. 2, 412-18 (April 15, 1961).

Magnetic properties are reported of powder compounds isomorphous to hausmannite, but containing partial to nearly complete substitution of diamagnetic  $\text{Zn}^{2+}$  or  $\text{Mg}^{2+}$  ions in the tetrahedral sites of  $\text{Mn}_3\text{O}_4$ . X-ray diffraction of these compounds reveals a single phase, whose structure corresponds to a tetragonally distorted spinel. Unidirectional anisotropy is present and is detected by the observation of hysteresis loops displaced along the field axis when the materials are cooled to low temperatures in magnetic fields of several kilo-oersteds. The unidirectional behaviour is stable to reverse field pulses of 140 kOe. An exchange anisotropy model is proposed involving interactions between ferrimagnetic and nearly antiferromagnetic regions brought about by the random distribution of the diamagnetic ions among the tetrahedral sites and the consequent magnetic inhomogeneity. This model is similar to that proposed for disordered alloy systems. Magnetic viscosity effects are observed which correspond in part to ordinary magnetic viscosity, but which are influenced by the presence of unidirectional anisotropy. The identity of this anisotropy is not impaired by the ordinary viscosity effects. In addition, observations of certain differences in the hysteresis loops measured dynamically and quasi-statically reveal an "extraordinary" viscosity associated with a gradual breakdown of the unidirectional anisotropy.

7769 STUDY OF THE INTERNAL FIELDS ACTING ON IRON NUCLEI IN IRON GARNETS, USING THE RECOIL-FREE ABSORPTION IN  $\text{Fe}^{57}$  OF THE 14.4 keV GAMMA RADIATION FROM  $\text{Fe}^{57}$ . R.Bauminger, S.G.Cohen, A.Marinov and S.Ofer. Phys. Rev. (USA), Vol. 122, No. 3, 743-8 (May 1, 1961).

The shape of the recoil-free absorption spectrum obtained in iron garnet absorbers was investigated, using a  $\text{Co}^{57}$  source embedded in stainless steel. The results confirm the existence of two iron sublattices each showing a Zeeman structure characterized by different parameters. No significant differences were detected between the Zeeman structure in yttrium iron garnet and dysprosium iron garnet. The values obtained for the effective magnetic field at the  $\text{Fe}^{57}$  nuclei at room temperature are  $3.90 \times 10^5$  and  $4.85 \times 10^5$  Oe for the d and a iron lattice sites, respectively. At liquid air temperature the corresponding fields are  $4.6 \times 10^5$  and  $5.4 \times 10^5$  Oe, respectively. The mean value of the chemical shift for the d sites relative to stainless steel is about  $0.04 \pm 0.005$  cm/sec and about  $0.06 \pm 0.005$  cm/sec for the a sites.

7770 MAGNETIC TORQUE CURVES FOR A SINGLE CRYSTAL OF THULIUM ORTHOFERRITE ( $\text{TmFeO}_3$ ).

C.Kuroda, T.Miyadal, A.Naemura, N.Nitzeke and H.Takata. Phys. Rev. (USA), Vol. 122, No. 2, 446-7 (April 15, 1961).

The magnetic anisotropy of a thulium orthoferrite single crystal was investigated by means of an automatically recording torque-magnetometer in the range between  $77^\circ$  and  $300^\circ \text{K}$ . It was found that at room temperature the direction of weak magnetization,  $\sigma_0$ , associated with an antiferromagnetic canted spin arrangement is parallel to the c-axis of the orthorhombic structure, and that at about  $100^\circ \text{K}$  a magnetic transition occurs, where the direction of  $\sigma_0$  changes from the c-axis to the a'-axis. The transition temperature obtained is the highest among those reported before on other orthoferrites. The torque curves obtained above the transition temperature are similar to those by Sherwood et al. (Abstr. 7161 of 1959) and can be explained by their model. The value of  $\sigma_0$  is equal to  $0.06 \mu_B/\text{mole}$  at room temperature. At  $77^\circ \text{K}$ , below the transition temperature, inexplicable torque curves were obtained in the b-plane. The curves showed a small jump at the c-axis superimposed on a  $\sin 2\theta$  curve with large amplitude. The jump amplitude is almost independent of the applied field in the range of 8500 to 30000 Oe. This behaviour cannot be explained by Sherwood's model, but it will give information on the interaction between thulium and ferric ions.

7771 THE ANTIFERROMAGNETIC SUSCEPTIBILITY AT MODERATE FIELDS. J.van den Broek and C.J.Gorter. Physica (Netherlands), Vol. 26, No. 8, 638-46 (Aug., 1960).

The isothermal differential susceptibility of an antiferromagnetic substance in a moderately strong magnetic field of arbitrary direction is calculated from the molecular field model as given by Gorter and Van Peski-Tinberger (Abstr. 5209 of 1956). The results are compared with the formulae of Nagamiya and Yosida and with experimental results on hydrated copper and manganese chlorides.

7772 THE POSSIBLE ANTIFERROMAGNETIC SYMMETRY GROUPS OF AZURITE. E.P.Riedel and R.D.Spence. Physica (Netherlands), Vol. 26, No. 12, 1174-84 (Dec., 1960).

Starting with the magnetic point group symmetry obtained by nuclear magnetic resonance techniques and the X-ray space group, Shubnikov group theory is employed to determine the possible antiferromagnetic symmetry groups of the monoclinic crystal azurite.

7773 NECESSITY AND EXPERIMENTAL CONSISTENCY OF ANTIFERROMAGNETIC GROUND STATE WITHOUT LONG-RANGE ORDER. G.W.Pratt, Jr.

Phys. Rev. (USA), Vol. 122, No. 2, 489-90 (April 15, 1961).

A proof is given that long-range order measured as the average value of the z component of sublattice magnetization of an antiferromagnet must be zero in the exact ground state if that state is non-degenerate and the Hamiltonian is invariant under time reversal. The neutron diffraction magnetic cross-section is shown not to depend on such a measure of long-range order.

7774 MAGNETIZATION AND ELECTRICAL RESISTIVITY OF ERBIUM SINGLE CRYSTALS.

R.W.Green, S.Legvold and F.H.Speeding. Phys. Rev. (USA), Vol. 122, No. 3, 827-30 (May 1, 1961).

The magnetic properties of erbium single crystals (h.c.p.) grown by the Bridgman method were determined in fields up to 18 kOe with the field applied parallel to and perpendicular to the c-axis at  $4.2^\circ \text{K}$  and between  $20.4^\circ$  and  $300^\circ \text{K}$ . The c-axis was found

to be the direction of easy magnetization. A Néel point was observed at 85°K. The ferromagnetic-antiferromagnetic transition temperature inferred from the magnetic data was 19.6°K. The saturation moment,  $\sigma_{\infty}$ , obtained by extrapolation of the c-axis data, was 8 Bohr magnetons compared to the theoretical 9. Electrical resistivity measurements from 1.3° to 300°K with the current parallel to the c-axis showed a sharp increase in resistivity at 20.4°K, the ferromagnetic-antiferromagnetic transition temperature; a large peak occurred at 53.5°K, and a minimum occurred at the Néel point. The a-axis resistivity curve showed a change in slope at the Néel point and was well behaved elsewhere.

#### 7775 UNUSUAL LOW-TEMPERATURE MAGNETIC BEHAVIOUR OF SOME CUBIC CRYSTALS.

M.B. Palma-Vittorelli, M.U. Palma, G.W.J. Drewes and W. Koerts. *Physica (Netherlands)*, Vol. 26, No. 11, 922-30 (Nov., 1960).

Electron spin resonance results on hexammine nickel halides are reported, which exhibit a low-temperature transition similar to that observed in some antiferromagnetics. Static susceptibility data, also reported, do not evidence such a low-temperature transition. These results are rather striking and they cannot easily be interpreted in terms of the current knowledge on antiferromagnetism. Some remarks and suggestions are given concerning their interpretation.

## Magnetic Resonances

#### 7776 THE EFFECT OF HETEROGENEITY OF THE MAGNETIC STRUCTURE ON THE WIDTH OF THE FERROMAGNETIC RESONANCE LINES. Yu.A. Izyumov.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 140-2 (July, 1960). In Russian.

It was shown analytically that, contrary to the conclusions reached by Clogston et al. (*J. Phys. Chem. Solids* (GB), Vol. 1, 129, 1956) imperfections of the magnetic structure of a ferromagnetic can, in fact, account for the broadening of the ferromagnetic resonance lines.

M.H. Sloboda

#### 7777 FERROMAGNETIC RESONANCE IN PERMALLOY FILMS.

A. Van Itterbeek, G. Forrez, J. Smits and J. Witters.

*J. Phys. Radium (France)*, Vol. 21, No. 2, 81-4 (Feb., 1960). In French.

An apparatus was developed to observe ferromagnetic resonance in thin films as a function of thickness. No dependence on the thickness of the film was found, but for certain films a resonance line with two maxima was observed. This is thought to be a consequence of inhomogeneities or stresses in the film. These factors mainly depend on the conditions of evaporation.

#### 7778 HIGHER APPROXIMATIONS IN THE THEORY OF FERROMAGNETIC RESONANCE.

S.V. Tyablikov and Pu Fu-cho. *Fiz. tverdogo Tela (USSR)*, Vol. 3, No. 1, 142-5 (Jan., 1961).

A short mathematical description of a method of calculating the Kubo splitting in a ferromagnetic (Abstr. 8437 of 1957). The method is based on the investigation of the many-valued temperature retarded Green's functions. Instead of the many-valued Green's work functions, the commutatory functions are used, since it is easier to obtain equations for them. [English translation in: *Soviet Physics-Solid State (USA)*].

N. Davy

#### 7779 RESTORATION OF STABILITY IN FERROMAGNETIC RESONANCE. H. Suhl.

*Phys. Rev. Letters (USA)*, Vol. 6, No. 4, 174-6 (Feb. 15, 1961).

The radiofrequency signal threshold of instability may be raised by imposing a time variation on the natural frequency of spin wave pairs otherwise liable to unstable growth. See also following abstract.

E.P. Wohlfarth

#### 7780 SUPPRESSION OF SUBSIDIARY ABSORPTION IN FERRITES BY MODULATION TECHNIQUES.

T.S. Hartwick, E.R. Peressini and M.T. Weiss.

*Phys. Rev. Letters (USA)*, Vol. 6, No. 4, 176-7 (Feb. 15, 1961).

The prediction by Suhl (preceding abstract), that the threshold power for subsidiary absorption of microwaves in ferrites can be increased by modulating the d.c. magnetic field, is verified by experiment. Curves are shown of the modulating field suppressing absorption as a function of frequency at different microwave powers

for a small sphere of yttrium iron garnet. Near the threshold microwave field the optimum modulation frequency is about 0.8 Mc/s. Suppression can be achieved at power levels as high as 10 dB above the threshold.

R. Parker

#### 7781 RELAXATION MECHANISMS IN FERROMAGNETIC RESONANCE. T. Kasuya and R.C. LeCraw.

*Phys. Rev. Letters (USA)*, Vol. 6, No. 5, 223-5 (March 1, 1961).

A preliminary account is given of a theory which explains the relaxation in yttrium iron garnet starting from a ferrimagnetic model. Some experimental results for  $\tau_k$  are presented and the dominant relaxation mechanisms elucidated.

D.J. Oliver

#### 7782 FERROMAGNETIC RESONANCE LINEWIDTH IN COBALT-SUBSTITUTED FERRITES.

C.W. Haas and H.B. Callen.

*Phys. Rev. (USA)*, Vol. 122, No. 1, 59-68 (April 1, 1961).

The effect of small concentrations of substitutional ions on the ferromagnetic resonance linewidth of a host ferrite is calculated. The resonance linewidth arises from magnon scattering induced by the variation from ion to ion of the spin-orbit interaction. This interaction is uniquely large for cobalt ions because of the orbital degeneracy of the ground state of the ion in a trigonally-symmetric crystalline field. The resultant contribution to the linewidth is found to be isotropic and of the order of 20-30 Oe for each per cent of cobalt in normal (i.e. noninverse) ferrites or in ferrous ferrite. In other ferrites the effect is diminished by the lifting of the ground-state orbital degeneracy at some of the cobalt sites; this diminution is calculated as a function of the degree of inversion.

#### 7783 CROSSOVER TRANSITIONS.

M.W.P. Strandberg.

*J. Phys. Chem. Solids (GB)*, Vol. 16, No. 1-2, 39-43 (Nov., 1960).

Finite-rotation operators are used to simplify the calculation of second-order, crossover transitions for a spin 3/2 system with trigonal symmetry. The resonant frequency and transition probabilities for the +3/2, -1/2 crossover transition with negative D (or +1/2, -3/2 with positive D) are calculated.

#### 7784 PARAMAGNETIC RESONANCE OF $Gd^{3+}$ IN $Al_2O_3$ .

S. Geschwind and J.P. Remeika.

*Phys. Rev. (USA)*, Vol. 122, No. 3, 757-61 (May 1, 1961).

The resonance spectrum of a small impurity of  $Gd^{3+}$  in  $Al_2O_3$  was examined at 24 kMc/s. The overall zero-field splitting of the ground state of 1.24 cm<sup>-1</sup> is among the largest so far observed for  $Gd^{3+}$ . The analysis of the spectra suggests that the  $Gd^{3+}$ , which has twice the ionic radius of aluminium, essentially entered substitutionally for the  $Al^{3+}$  (but distorted the environment in such a way as to approach a condition of nine-fold oxygen coordination, the symmetry still remaining  $C_3$ ). The substitution of  $Gd^{3+}$  for  $Al^{3+}$  whose ionic radius is half as large would indicate that at impurity levels less than 0.02% matching of ionic radii is not an all-important criterion for incorporation into the lattice. Although there are two types of Al sites which are physically equivalent, the  $Gd^{3+}$  entered selectively into one of these sites. This seemingly paradoxical result is ascribed to the dynamics of the crystal growth. The sites referred to are actually inequivalent during the growth process as the Gd falls into place and are only equivalent in the grown crystal.

#### 7785 COMMENTS ON THE EPR SPECTRUM OF $Mn^{++}$ IN CALCITE. L.M. Materrese.

*J. chem. Phys. (USA)*, Vol. 34, No. 1, 336 (Jan., 1961).

The purposes of the letter are (a) to provide an explanation for the weak lines in the e.s.r. spectrum reported by Kikuchi and Materrese (Abstr. 13871 of 1960), (b) to call attention to a feature which was neglected in their treatment of the doublet splitting of the fine structure, and (c) to mention briefly the results of a low-temperature investigation of the  $\Delta M = \pm 2$  spectrum that was found in this system.

J.M. Baker

#### 7786 EFFECTS OF HYDROSTATIC PRESSURE ON THE PARAMAGNETIC RESONANCE SPECTRA OF SEVERAL IRON GROUP IONS IN CUBIC CRYSTALS. W.M. Walsh, Jr.

*Phys. Rev. (USA)*, Vol. 122, No. 3, 762-71 (May 1, 1961).

The magnetic resonance spectra of  $Cr^{3+}$ ,  $Mn^{2+}$ ,  $Fe^{3+}$ , and  $Ni^{2+}$  present as substitutional impurities in MgO crystals and powders, and of  $Mn^{2+}$  in cubic ZnS, were observed as functions of hydrostatic pressure at room temperature. The results are interpreted assuming the local compressibilities to be equal to those of the pure host lattices. The measured volume dependence of the orbital

contributions to the magnetic moments of the F-state ions,  $\text{Cr}^{3+}$  and  $\text{Ni}^{2+}$ , are consistent with a point-charge model within the experimental error. This simple model can only crudely account for the observed magnitudes of the orbital singlet-triplet splittings, however. The pressure dependences of the cubic field splittings of the S-state ions,  $\text{Mn}^{2+}$  and  $\text{Fe}^{3+}$ , are identical in  $\text{MgO}$  and correspond roughly to a fourth power law if an ionic potential is assumed. The cubic field parameter for  $\text{Mn}^{2+}$  in  $\text{ZnS}$  varies half as rapidly with volume. These results are consistent with recent calculations of Powell, Gabriel, and Johnston if it is assumed that the volume dependence of the cubic potentials in these lattices are given by the ionic model, though the relative magnitudes are not. The hyperfine structure of the manganese spectra also proves sensitive to sample volume, particularly in the sulphide. The effect may be qualitatively understood in terms of the exchange-polarization theory of the strong electron-nuclear interaction.

7787 ELECTRON SPIN RESONANCE IN A GAMMA-IRRADIATED SINGLE CRYSTAL OF THIODIGLYCOLIC ACID. Y. Kurita and W. Gordy.

J. chem. Phys. (USA), Vol. 34, No. 4, 1285-91 (April, 1961).

The electron spin resonance was measured at room temperature at 9 kMc/s. From the analysis of the anisotropy in the spectroscopic splitting factor and in the nuclear hyperfine interaction constants, a model of the free radical  $\text{HOOC}-\text{CH}_2-\text{S}-\text{CH}-\text{COOH}$  is proposed. In this free radical, the electron spin density is mainly in a  $\pi$  orbital, about 60% of which is the p orbital of the CH carbon, 2% is the 1s orbitals of the  $\text{CH}_2$  hydrogens, and 22% is in the p orbital of the S.

7788 CROSS-DOPING AGENTS FOR RUTILE MASERS. P. F. Chester.

J. appl. Phys. (USA), Vol. 32, No. 5, 866-8 (May, 1961).

The e.s.r. spectra of nonstoichiometric rutile and rutile doped with tantalum, niobium, and cerium were examined at helium temperatures.  $\text{Ta}^{4+}$  and  $\text{Nb}^{4+}$  have short spin-lattice relaxation times and appear to be suitable for cross doping in maser applications.

7789 ON THE THEORY OF SPIN-SPIN RELAXATION. I. W. J. Caspers.

Physica (Netherlands), Vol. 26, No. 10, 778-97 (Oct., 1960).

A method is developed that enables the determination of the asymptotic form for large times of the so-called relaxation function of spin systems, in the case of a large external magnetic field H. The spin-spin relaxation phenomena are described within the framework of the spin Hamiltonian; restriction is made to those systems for which all g-tensors appearing in the spin Hamiltonian are isotropic. Most attention is paid to those systems in which all ions are identical and occupy equivalent lattice sites. For these systems the asymptotic form of the relaxation function is given by a function of the type:

$$A \exp(-t/\tau) + B,$$

in which expression  $\tau$  is the spin-spin relaxation time. For the quantity  $1/\tau$  a series expansion is found:

$$1/\tau = \sum_{n=1}^{\infty} 1/\tau_n,$$

in which the different terms  $1/\tau_n$  correspond to different relaxation processes. For more complicated systems the ions are divided into groups, according to the kind of ion and the occupied lattice site. When all ions have the same g-value and the interaction between the different groups is strong enough, the asymptotic form of the relaxation function is in a good approximation of the type indicated above, indicating that there is only one relaxation time. If this coupling is small there is in general a number of different relaxation times, this number being equal to the number of groups. The same is true for systems, containing different groups, corresponding with different g-values.

7790 ON THE THEORY OF SPIN-SPIN RELAXATION. II. W. J. Caspers.

Physica (Netherlands), Vol. 26, No. 10, 798-808 (Oct., 1960).

The method for computing spin-spin relaxation times, developed in Pt I is worked out in more detail for systems containing only one magnetic specimen. Numerical calculations are performed for two types of lattices, and the results are compared with the experimental value of  $\tau$  for the ammonium cupric Tutton salt. Finally,

a discussion of older theories on spin-spin relaxation is given and a comparison of these theories is made, regarding the theoretical foundation as well as the numerical results.

7791 ON THE THEORY OF SPIN-SPIN RELAXATION. III. W. J. Caspers.

Physica (Netherlands), Vol. 26, No. 10, 809-24 (Oct., 1960).

A typical relaxation mechanism is studied for which the change in magnetic energy, accompanying a spin flip, is compensated or partly compensated by the change in electric energy. The spin flips are all two or more spin processes for this mechanism. An essential part of the argument is the partition of the operators of the total magnetic moment and of the total spin moment in a diagonal and a nondiagonal part, in a representation diagonalizing the zero order hamiltonian, containing only the one spin parts of the total spin total spin hamiltonian (Zeeman parts and electric parts). Only the diagonal parts of the moments contribute to the spin-spin relaxation. Just as for the more simple case, treated in Pt I and II, the number of relaxation times equals the number of groups of ions. Most attention is paid to simple systems, containing only one group.

7792 STIMULATED SPIN-ECHO MEASUREMENT OF CROSS-RELAXATION IN NEUTRON-IRRADIATED CALCITE. L. K. Wanlass and J. Wakabayashi.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 271-3 (March 15, 1961).

The Hahn spin-echo technique (Abstr. 2922 of 1951) was used at 8.807 kMc/s to study stimulated e.p.r. spin echoes occurring due to cross relaxation between the three spectral lines of neutron-irradiated calcite at 1.5°K. Results obtained show that when the normal spin-lattice relaxation time  $T_1$  is longer than the cross-relaxation time,  $T_{21}$  this technique yields a single exponential decay curve to  $T_{21}$ . The value obtained at 1.5°K is  $T_{21} = 600 \mu\text{sec}$  ( $T_1 = 5 \pm 2 \text{ sec}$ ). The use of this technique for studying inhomogeneously broadened lines is considered.

S. A. Aherr

7793 THE SPIN-SPIN RELAXATION OF DPPH IN PARALLEL FIELDS. J. C. Verstelle, G. W. J. Drewes and C. J. Gorter.

Physica (Netherlands), Vol. 26, No. 7, 520-8 (July, 1960).

A method is described for measuring both components of the complex susceptibility,  $\chi = \chi' - j\chi''$  by means of a twin T bridge circuit. The results of some measurements in parallel static fields for a DPPH sample are given. The relaxation time  $\tau$  is found to depend on the external static field.

7794 THE INFLUENCE OF THE MAGNETIC FIELD MODULATION ON THE NUCLEAR POLARIZATION IN THE OVERHAUSER EFFECT. K. H. Rädler.

Ann. Phys. (Germany), Vol. 7, No. 1-2, 45-9 (1961). In German.

It is shown that nuclear polarization calculations lead to appreciably different results depending on whether the magnetic field modulation is considered or neglected. Only if the line width of the electron resonance is large compared to the modulation amplitude can the effects of the modulation on the polarization be safely ignored.

P. M. Parke

7795 APPARENT TEMPERATURE DEPENDENCE OF N.M.R. SECOND MOMENT. A. Miyake.

Rep. Liberal Arts Sci. Fac. Shizuoka Univ. (Nat. Sci.) (Japan), Vol. 2, No. 6, 233-6 (March, 1960).

The apparent effect obtained from the observed absorption line is explained in terms of the cutting off the long tails of a narrowed absorption line, by means of the correlation time theory. Alternative explanations are by assuming an approximately Lorentzian line shape, or by means of the frequency modulation theory using the picture of local magnetic field. 1/4 effect of an axial rotation on the second moment, indicated by Gutowsky-Pake (see Abstr. 5180 of 1950) is explained from this point of view.

7796 MACROSCOPIC EQUATIONS OF DOUBLE RESONANCE THERMODYNAMIC INTERPRETATION. J. L. Motchane and J. Uebbersfeld.

J. Phys. Radium (France), Vol. 21, No. 3, 194-8 (March, 1960). In French.

These equations are used to compute the nuclear polarization which can be obtained by inducing a "forbidden" transition in a system of a nuclear and an electronic spin in static interaction. The statistical interpretation of this result is given in terms of the method described by Kittel (Abstr. 11327 of 1954) for the Overhauser effect.

7797 DYNAMIC POLARIZATION OF NUCLEI BY THERMAL CONTACT BETWEEN SPIN SYSTEMS. M.Goldman and A.Landesman. C.R. Acad. Sci. (France), Vol. 252, No. 2, 263-5 (Jan. 9, 1961). In French.

A new method of dynamic polarization of nuclei is discussed. One can obtain, in para-dichlorobenzene, polarizations of the protons eight times bigger than the maximum theoretically possible using the "solid effect". In zero or very small steady magnetic field a radio-frequency field is applied at a frequency near to the chlorine quadrupole splitting; this enables the proton and chlorine spin systems to come into thermal equilibrium, and produces the proton polarization. The results of some successful experiments using the new technique are reported. J.M.Baker

7798 CHEMICAL SHIFTS OF THE NUCLEAR MAGNETIC RESONANCE SIGNALS OF FLUORINE IN IONIC CRYSTALS. Van I-tsyu [Wang I-ch'iu]. Dokl. Akad. Nauk SSSR, Vol. 136, No. 2, 317-19 (Jan. 11, 1961). In Russian.

The shift in fluorides of the alkali and alkaline-earth metals was measured using a radio-frequency spectrometer which recorded the derivative of the nuclear magnetic resonance (n.m.r.) line; the r.f. generator was in principle that of Gutowsky et al. (Abstr. 8633 of 1953). Small-amplitude modulation of the magnetic field was used to prevent distortion of the centre of a weak line of the solid by the strong line of the liquid standard (aqueous solution of KF). It was found that the chemical shift (and the magnetic screening) decreases as the atomic number of the metal increases (except in LiF). [English translation in: Soviet Physics-Doklady (USA)]. F.Lachman

7799 KNIGHT SHIFT IN POTASSIUM, INDIUM AND YTTRIUM METALS. W.H.Jones, Jr, T.P.Graham and R.G.Barnes. Acta metallurgica (Internat.), Vol. 8, No. 9, 663-4 (Sept., 1960). Values are reported, as in the table below.

| Nucleus           | Reference                 | Temp., °C | Magnetic field, Oe | $\frac{\Delta H}{H}$ % |
|-------------------|---------------------------|-----------|--------------------|------------------------|
| K <sup>39</sup>   | H.COOK (aq.)              | 25        | 12400              | 0.265 ± 0.002,         |
| In <sup>115</sup> | InBr <sub>3</sub> (aq.)   | 130-200   | 10300              | 0.794 ± 0.002,         |
| Y <sup>89</sup>   | YCl <sub>3</sub> (in HCl) | 25        | 10200              | 0.337 ± 0.005.         |

The probability densities at the nucleus in the potassium atom,  $|\psi_A(0)|^2$ , and in the metal,  $\langle |\psi_F(0)|^2 \rangle_{ar}$ , and their ratio are calculated, giving

$$\begin{aligned} |\psi_A(0)|^2 &= 1.1086 \text{ Bohr units,} \\ \langle |\psi_F(0)|^2 \rangle_{ar} &= 1.035 \text{ Bohr units,} \\ \text{ratio} &= 0.934. \end{aligned}$$

S.A.Ahern

7800 EFFECT OF DILUTE SOLID SOLUTIONS OF IRON AND OF NICKEL ON THE NUCLEAR RESONANCE OF Co<sup>59</sup>. R.C.La Force, S.F.Ravitz and G.F.Day. Phys. Rev. Letters (USA), Vol. 6, No. 5, 226-8 (March 1, 1961).

Iron stabilizes the f.c.c. form of cobalt, thus removing one resonance line, but gives rise to three further lines. Similar results are observed for nickel. The results are considered in relation to the direct interaction between an impurity atom and a nearest neighbour matrix atom and also to the spin polarization produced about an impurity centre by the scattering of conduction electrons. The general explanation seems to be satisfactory. D.J.Oliver

MAGNETIC INTERACTION OF Gd<sup>3+</sup>. See Abstr. 7524

7801 NUCLEAR MAGNETIC RESONANCE SATURATION IN NaCl AND CaF<sub>2</sub>. W.I.Goldburg. Phys. Rev. (USA), Vol. 122, No. 3, 831-6 (May 1, 1961).

Experiments were performed to test the hypothesis due to Redfield (Abstr. 7257 of 1955), that a nuclear spin system in a sufficiently large r.f. field, H<sub>1</sub>(ν), is properly described by a spin temperature referred to a frame of reference rotating about the Zeeman field with the frequency ν of the r.f. field. Measurements were made on the Na<sup>23</sup> spins in NaCl and the F<sup>19</sup> spins in CaF<sub>2</sub>. A combination of steady-state and pulse techniques was used to measure the magnetization M<sub>z</sub> as a function of the frequency and amplitude of H<sub>1</sub>(ν). When H<sub>1</sub> is sufficiently large, the data show that Redfield's theory is correct within 10% for NaCl but appreciably in error for CaF<sub>2</sub>. The same type of measurement performed at low

amplitudes of H<sub>1</sub> show that the theory of Bloembergen, Purcell and Pound (Abstr. 2529 of 1948) is in agreement with the NaCl measurements but measurably in error for CaF<sub>2</sub>. It is suggested that neither theory is correct for CaF<sub>2</sub> because the fluorine spins relax by means of paramagnetic impurities and therefore do not relax independently with characteristic time T<sub>1</sub>, as is assumed in both theories. In an intermediate range of saturating field amplitudes, neither theory is expected to apply; this was found to be the case experimentally.

7802 NUCLEAR MAGNETIC RESONANCE IN TANTALUM METAL. J.I.Budnick and L.H.Bennett. J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 37-8 (Nov., 1960).

The nuclear magnetic resonance of Ta<sup>181</sup> was observed in tantalum metal. The sample was a stack of high purity foil which was degassed and annealed. No resonance was observed in tantalum metal powder.

7803 NUCLEAR MAGNETIC RESONANCE OF Tb<sup>159</sup> IN POWDERED METALLIC TERBIUM IN THE FERRO-MAGNETIC STATE. J.Hervé and P.Veillet. C.R. Acad. Sci. (France), Vol. 252, No. 1, 99-101 (Jan. 4, 1961). In French.

A strong absorption line was observed at (3047 ± 2) Mc/s in an experiment at 77° K. This frequency agrees quite well with calculations based on measurements of the hyperfine splitting (Abstr. 1883 of 1959) of Tb<sup>++</sup>. D.J.Oliver

7804 INFLUENCE OF AN APPLIED FIELD ON THE NUCLEAR RESONANCE OF Fe<sup>57</sup> IN THE LOCAL FIELD OF YTTRIUM IRON GARNET. C.Robert. C.R. Acad. Sci. (France), Vol. 252, No. 10, 1442-4 (March 6, 1961). In French.

Nuclear magnetic resonance of Fe<sup>57</sup> situated on the d-sites of yttrium iron garnet was studied as a function of applied field. The theory of the augmentation of the effective radio-frequency field in the domain walls is shown to be applicable. The shift in resonant frequency is linear with applied field above the field at which all domain walls vanish. The resonant frequency decreases with applied field showing that the local field at the d-site Fe<sup>57</sup> nucleus is negative. The relaxation times, T<sub>1</sub> and T<sub>2</sub>, are also measured as a function of applied field. The relation T<sub>1</sub> =  $\frac{1}{2}$  T<sub>2</sub> is seen to be obeyed. P.E.Seiden

7805 NUCLEAR MAGNETIC RESONANCE OF Fe<sup>57</sup> IN THE LOCAL FIELD OF YTTRIUM IRON GARNET. C.Robert. C.R. Acad. Sci. (France), Vol. 251, No. 23, 2684-6 (Dec. 5, 1960).

Measurements were made on the nuclei in both octahedral and tetrahedral sites in powder specimens. At room temperature the frequencies are 67.2 and 54.15 Mc/s at these two sites respectively and measurements over a range of temperatures extrapolate to about 77 and 65 Mc/s respectively at T = 0. The relaxation times T<sub>1</sub> and T<sub>2</sub> are also given as a function of temperature. J.M.Baker

7806 EFFECTS OF DISTRIBUTION OF CORRELATION TIMES UPON T<sub>1</sub> AND T<sub>2</sub> IN NUCLEAR MAGNETIC RESONANCE [OF POLYMERS]. A.Odajima. Suppl. Progr. ther. Phys. (Japan), No. 10, 142-58 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The relaxation times T<sub>1</sub> and T<sub>2</sub> and the activation energy of segment motion in the nuclear magnetic resonance (NMR) of polymer systems are explained by consideration of the distribution of correlation times. The experimental relations between T<sub>1</sub> and T<sub>2</sub> in many kinds of compounds show that the theories of Bloembergen et al. (Abstr. 2529 of 1948) and of Kubo and Tomita (Abstr. 2881 of 1959), in which the Brownian motion of a segment is treated by the assumption of the one correlation time, are not sufficiently applicable to T<sub>1</sub> and T<sub>2</sub>. On the other hand, the low value of apparent activation energy obtained from NMR measurements is dependent upon the assumption of one correlation time in the above theories. Furthermore, in order to obtain a quantitative explanation of the experimental curve of T<sub>1</sub> it is postulated in the present theory that the apparent activation energy E<sub>N</sub> is dependent upon temperature rather than constant, as the energies in the mechanical and dielectric relaxation. The activation energy E<sub>N</sub> versus temperature relation is obtained from the data on T<sub>1</sub> and T<sub>2</sub> which have been measured for natural rubber. The shape of the E<sub>N</sub>-curve is in remarkably good agreement with that of the EM-curve already reported.

# 7807 NUCLEAR QUADRUPOLE RESONANCE IN AN ANTI-FERROMAGNET.

J.C.Burgiel, V.Jaccarino and A.L.Schawlow.

Phys. Rev. (USA), Vol. 122, No. 2, 429-36 (April 15, 1961).

Nuclear quadrupole resonance techniques were used to investigate magnetic interactions in the bromates and iodates of certain 3d transition metal ions. In particular, for  $\text{Ni}(\text{IO}_3)_2 \cdot 2\text{H}_2\text{O}$  there is an abrupt disappearance of the  $\text{I}^{127}$  ( $\pm 3/2 \leftrightarrow \pm 1/2$ ) transition at  $3.08^\circ\text{K}$ ; at lower temperatures there is a large, temperature-dependent splitting. This behaviour is attributed to the combined effects of an antiferromagnetic ordering of the  $\text{Ni}^{2+}$  electron spins and a h.f.s. interaction of the nonlocalized  $\text{Ni}^{2+}$  spin magnetization with the  $\text{I}^{127}$  nuclear magnetic moment. Measurements of the pure quadrupole transition frequencies above, and of their temperature-dependent splittings below the Néel temperature, yield the quadrupole coupling constant, the asymmetry of the electric field gradient (EFG) tensor, and the sublattice magnetization as a function of temperature. Qualitative experiments at  $1.3^\circ\text{K}$  indicate  $T_1^{127} \ll 100$  sec and  $T_2^{127} \sim 10^{-8}$  sec. Measurements of the r.f. and d.c. magnetic susceptibility were made and are consistent with these conclusions and, in addition, indicate the sudden onset of a spontaneous ferromagnetic moment as the temperature is lowered below  $T_N$ . A possible isotope effect on the  $T_N$  of  $\text{Ni}(\text{IO}_3)_2 \cdot 2\text{H}_2\text{O}$  was looked for but none was found. Cupric iodate and the bromates give no evidence of magnetic ordering above  $1.3^\circ\text{K}$ .

# 7808 THE NUCLEAR QUADRUPOLE AND ELECTRON SPIN RESONANCE SPECTRA OF SOME CHLORINE COMPOUNDS INCLUDING $(\text{Me}_3\text{PhN})(\text{FeCl}_4)$ .

C.D.Akon and T.Iredale.

J. chem. Phys. (USA), Vol. 34, No. 1, 340-1 (Jan., 1961).

$\text{Cl}^{35}$  quadrupole resonances were observed in  $\alpha$ - $\omega$ -( $\text{CH}_2$ ) $_n\text{Cl}_2$  for  $n = 2, 4$  but not for  $n = 3, 5$ , and in the  $\beta$ -form of chloropropionic acid but not in the  $\alpha$ -form. The negative results are unexplained. An absorption band in  $(\text{Me}_3\text{PhN})(\text{FeCl}_4)$  was eventually identified as an electron spin resonance. E.F.W.Seymour

## MECHANICAL PROPERTIES OF SOLIDS

EFFECT OF THE APPARENT SECOND-ORDER TRANSITION OF HIGH POLYMERS ON THEIR MECHANICAL PROPERTIES. See Abstr. 7879

# 7809 NOTES AND REFERENCES FOR THE MEASUREMENT OF ELASTIC MODULI BY MEANS OF ULTRASONIC WAVES.

H.J.McSkimin.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 606-15 (May, 1961).

Aspects of wave propagation of particular importance for the measurement of elastic moduli of solids are first reviewed. Experimental techniques are then discussed, with notes on the suitability for a given application and on factors affecting the accuracy of results. References to the more detailed descriptions are listed.

USE OF A TENSILE TESTING MACHINE FOR THE DETERMINATION OF STRESS AND STRAIN-OPTICAL COEFFICIENTS. See Abstr. 7703

# 7810 THIRD-ORDER ELASTIC MODULI OF GERMANIUM.

T.Bateman, W.P.Mason and H.J.McSkimin.

J. appl. Phys. (USA), Vol. 32, No. 5, 928-36 (May, 1961).

Measurements were made for all six third-order elastic moduli of germanium by measuring ultrasonic velocities in selected directions when directed static stresses are applied to the crystal. Three measurements were obtained by using hydrostatic pressures, three by using a static compression along the  $\langle 001 \rangle$  axis, and six by stressing the  $\langle 110 \rangle$  axis with measurements being made along the  $\langle 001 \rangle$  direction and the  $\langle 110 \rangle$  direction. Using the finite strain formulas of Murnaghan, the measured velocities are related to the three second-order elastic moduli and the six third-order elastic moduli for a cubic crystal. The 12 sets of measurements provide considerable overlap, and the probable errors are shown to be moderate.

# SOME VISCO-ELASTIC PROPERTIES OF NYLON.

7811 F.L.Warburton, J.F.P.James and S.Hother-Lushington.

Brit. J. appl. Phys., Vol. 12, No. 5, 230-7 (May, 1961).

The dynamic modulus of nylon fibres was measured over a wide frequency range at different temperatures and humidities, and also the life under load. The measured life times were of the same order as the periods used in the dynamic experiments. The results of both sets of experiments can be explained on the assumption that increase in temperature only affects the internal friction of nylon, whereas the absorption of water has also a significant although smaller effect on the elastic properties.

# 7812 THE INFLUENCE OF HEAT TREATMENT ON THE SHEAR MODULUS AND THE CURIE POINT OF THE ALLOY ELINVAR.

V.V.Propastina.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1105-9 (1958). In Russian.

This alloy has a high modulus of elasticity and a thermo-elastic coefficient which varies slightly. As opposed to other alloys in which, on increasing the temperature, an almost linear decrease in the elastic modulus occurs, in Elinvar the elastic modulus is practically unchanged up to the Curie point and only on heating above the Curie point does the value of the modulus decrease. Such anomalous behaviour is connected with its ferromagnetic properties and explains the presence of the volume effect, brought about by the thermo-contraction of the paraprocess  $(d\lambda_t/dt)_N$  which arises from a decrease in the vector of the spontaneous magnetization of the region  $I_S$  on heating, and the thermo-contraction  $(d\lambda_t/dt)_M$  governed by the redistribution of the vectors of the spontaneous magnetization of  $I_S$  as a result of the removal of the internal elastic stresses on heating. These magnetic effects are particularly large at the Curie point when the alloy passes into the paramagnetic state. Under production conditions, occasions are observed when springs prepared from alloys of one and the same composition have different thermo-elastic properties as a result of a deviation from the technological process of their preparation. A study of the influence of the technological factors on the thermoelastic properties of the alloy enables the nature of the anomaly to be explained more fully. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 147-52 (1958)].

7813 ULTRASONIC DETECTION OF CHANGES IN THE ELASTIC PROPERTIES OF A 70-30 IRON-NICKEL ALLOY UPON HEAT TREATMENT. E.P.Papadakis and E.L.Reed. J. appl. Phys. (USA), Vol. 32, No. 4, 682-7 (April, 1961).

Ultrasonic attenuation and velocity measurements were made by the pulse-echo method on specimens after various steps in their transformation from austenite to martensite. It was found that the attenuation from Rayleigh scattering decreased, while that from elastic hysteresis increased as the transformation proceeded. It was concluded that the presence of the small martensite platelets in the grains reduced the anisotropy of the elastic constants of the grains, thus reducing the Rayleigh scattering. The increase in the hysteresis parallels the increase in residual strain and the increase in grain boundary material attending the transformation.

7814 INTERNAL FRICTION AND THE ABSORPTION OF SOUND IN SYSTEMS WITH ADDITIONAL INTERNAL PARAMETERS. V.T.Shmatov. Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 984-93 (1958). In Russian.

Formulae are derived for the value of internal friction, the velocity and coefficient of absorption of sound in systems with one or several additional internal parameters. Near the point of phase transition of the second kind (if it is caused by the existence of an additional internal parameter) a connection is established between the jumps of elastic moduli and the value of internal friction and the connection between the jump in the square of the velocity and the value for the coefficient of absorption of sound. The internal friction and absorption of sound near the Curie point are maxima. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 984-93 (1958)].

7815 THE RECOVERY OF INTERNAL FRICTION OF ALUMINIUM, SILVER AND PLATINUM AFTER THE REMOVAL OF THE LOAD. A.Ya.Samoilova and V.S.Postnikov. Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1081-7 (1958). In Russian.

The recovery was studied after small deformations by small amplitude, low-frequency vibrations ( $\nu = 1$  c/s). Values were

obtained for the heat of activation of the recovery process: 4500 (Al), 6400 (Ag) and 8000 (Pt) cal/mole. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 124-9 (1958)].

**7816 LOW-FREQUENCY MEASUREMENTS ON THE BORDONI INTERNAL FRICTION PEAK IN COPPER.**

D.H.Niblett.

J. appl. Phys. (USA), Vol. 32, No. 5, 895-9 (May, 1961).

An apparatus is described for the measurement of the internal friction of metals over the temperature range of 4-300°K at a frequency of the order of 10 c/s. The Bordoni internal friction peak was observed in pure polycrystalline copper at 62°K at a frequency of 13.4 c/s. By comparison with measurements at high frequencies, a value of 0.14 eV is deduced for the activation energy. The width of the Bordoni peak is discussed in terms of distributions of activation energies and attempt frequencies.

**7817 APPARATUS FOR MEASURING INTERNAL FRICTION AND MODULUS CHANGES OF METALS AT LOW FREQUENCIES.** J.C.Swartz.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 335-8 (March, 1961).

A description is given of a torsion pendulum and associated apparatus which were employed in measuring internal friction and modulus changes due to dislocations. The pendulum is contained in an evacuated chamber. One specimen chamber is used for temperatures between 80 and 400°K and another for the range 290 to 1000°K. Decrements above  $4 \times 10^{-5}$  were observed at maximum strain amplitudes in the range  $2 \times 10^{-7}$  to  $2 \times 10^{-4}$ . Modulus changes may be measured within 1 part in  $10^4$ . The specimens may be plastically deformed in situ at temperature. A method is described for making measurements with an elastic torsional bias stress on the specimen.

**7818 A CONTRIBUTION TO THE THEORY OF RELAXATION PHENOMENA IN SOLID BODIES.** T.D.Shermergor.

Fiz. Metallov i Metallovedenie (USSR), Vol. 6, No. 6, 1077-80 (1958). In Russian.

A thermodynamic calculation of the stress tensor for inhomogeneous isotropic infinite solid bodies is carried out. It is shown that, in a general case, the dynamic modulus is determined by the spectrum of the relaxation times. [English translation in: Phys. Metals and Metallography (GB), Vol. 6, No. 6, 119-23 (1958)].

**7819 THERMODYNAMIC BASIS OF RELAXATION SPECTROMETRY.** K.Okano.

Suppl. Progr. theor. Phys. (Japan), No. 10, 5-18 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). Meixner's theory of anisotropic viscoelasticity (Abstr. 569 of 1955) is extended to the case in which stimulus and response are thermodynamic variables in general; several characteristic features of response functions, which describe the departures of a macroscopic homogeneous system from thermodynamic equilibrium produced by time-dependent external disturbances, are discussed at some length from a purely phenomenological standpoint of irreversible thermodynamics. Some conclusions, which may be of some use in relaxation spectrometry, are obtained regarding, for example, the characteristic types of response functions and interrelationships among several response functions.

**7820 ON THE MECHANICAL RELAXATION TIME SPECTRA OF CRYSTALLINE POLYMERS.** K.Nagamatsu.

Suppl. Progr. theor. Phys. (Japan), No. 10, 73-81 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The time-temperature superposition principle of viscoelasticity was found to be applicable also to crystalline polymers. Using this superposition principle the relaxation time spectra of several crystalline polymers were determined by systematic measurements on stress relaxation. Some rheological properties of crystalline polymers are interpreted on the basis of these relaxation time spectra and the apparent energy of activation. As an example the calculated relation of mechanical loss tangent versus temperature for polytrifluorochloroethylene is shown to be in good agreement with that obtained by the observation of damping free oscillation. Comparison of these results on the temperature dependency of mechanical loss tangent has revealed the relation between the viscoelasticity of crystalline polymers and the glass transition temperature: the maximum in the  $\tan \delta$  versus temperature curve has been found to have a rheological character and to depend on the time scale of observation. Viscoelasticity in the temperature range lower than the glass temperature has been

studied thoroughly for crystalline polymers, in contrast with the case of amorphous polymers where observations on the viscoelasticity in the temperature range higher than the glass temperature is well established. A system is proposed to describe the rheological properties of crystalline polymers by application of the superposition principle.

**7821 DISLOCATION RELAXATION SPECTRA OF COLD-WORKED BODY-CENTERED CUBIC TRANSITION METALS.** R.H.Chambers and J.Schultz.

Phys. Rev. Letters (USA), Vol. 6, No. 6, 273-5 (March 15, 1961).

Various peaks were found in the internal friction versus temperature curves in the body-centred cubic metals Nb, Ta, Mo and W. These peaks appear only with prior plastic deformation and their variation of shape with annealing history is described in some detail. On the basis of these observations the authors consider that the defects responsible for the relaxation spectra in the cold-worked b.c.c. metals are similar to those that produce the Bordoni peaks in the face-centred cubic metals. R.Bullough

**7822 PHENOMENOLOGICAL THEORY OF NON-LINEAR VISCOELASTICITY.** M.Yamamoto.

Suppl. Progr. theor. Phys. (Japan), No. 10, 19-35 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). Two three-dimensional models are introduced in order to describe the non-linear behaviour and the three-dimensional cross effects occurring in the stress-deformation relations of viscoelastic materials. These models are the analogues of the so-called Maxwell and Voigt models in the classical one-dimensional case. Non-linearities in the stress-deformation relations are classified into three categories: elastic, viscous and geometrical ones, which are connected with the energy stored and dissipative mechanisms and the three-dimensional character of the materials, respectively. It is pointed out that one can actually separate these three non-linearities by observing the structural viscosity and the Weissenberg effect. The viscoelasticity of the so-called weakly coupled network model is briefly discussed as an example of the three-dimensional Maxwell model.

**7823 VISCOELASTIC PROPERTIES OF NETWORK STRUCTURE.** S.Hayashi.

Suppl. Progr. theor. Phys. (Japan), No. 10, 82-100 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). The statistical mechanics of a modified rubber-like network structure are investigated in order to formulate a molecular theoretical explanation of the viscoelastic behaviour of amorphous high-polymers. In one of the theories discussed, the relaxation mechanism is described by the breakage and reformation of junctions, and in the other, use is made of the concept of the slipping of chains for the relaxation mechanism. It is shown that these two theories have similar results. It is thus concluded that the concept of slipping of chains is essentially equivalent to that of the rearrangement of chains caused by the breakage and reformation of junctions. Furthermore, the stress-strain-time relations of these models are essentially equivalent to those of the so-called generalized Maxwell model in the phenomenological theory of viscoelasticity.

**MOLECULAR THEORY OF RELAXATION PHENOMENA IN POLYMERS.** See Abstr. 7505

**GENERAL THEORY OF RELAXATIONS IN THE POLYMER CHAIN.** See Abstr. 7506

**TEMPERATURE-DEPENDENT COMPRESSIBILITY IN SUPERCONDUCTORS.** See Abstr. 6998

**7824 PENETRATION OF A SHARPENED AXIALLY-SYMMETRICAL BODY INTO SOILS.** A.Ya.Sagomanyan.

Dokl. Akad. Nauk SSSR, Vol. 134, No. 6, 1320-3 (Oct. 21, 1960). In Russian.

For abstract, see Abstr. 5081 of 1961. [English translation in: Soviet Physics - Doklady (USA), Vol. 5, No. 5, 989-92 (March-April, 1961)].

**7825 THE DISTRIBUTION OF DEFORMATION IN LEAD FATIGUED IN VACUO.** K.U.Snowden.

Phil. Mag. (GB), Vol. 6, 321-7 (March, 1961).

Observations were made on the nature of the deformation, hardening, and recrystallization in polycrystalline specimens of high-purity lead fatigued in reverse-plane bending in vacuo (approx.  $5 \times 10^{-3}$  or  $2 \times 10^{-2}$  mm Hg). Fatigue straining induced slip, and

grain boundaries to migrate to more stable positions at  $\pm 45$  degrees to the principal stress axis. The early distribution of slip-trace angles was in good agreement with the angular distribution which Hedgepath (1952) predicted on a basis of the maximum shear stress criterion and by neglecting the slip and grain-boundary interaction. Evidence for this latter interaction was found as hard zones up to 100 microns wide near grain boundaries. These zones were the sites for recrystallization and grain growth.

**CHARGE EFFECTS DURING INHOMOGENEOUS DEFORMATION OF ROCKSALT.** See Abstr. 7629

**CHANGE OF SPECIFIC HEAT OF METALS DURING PLASTIC DEFORMATION.** See Abstr. 7535

**7826 CREEP BEHAVIOR OF PORE-FREE POLYCRYSTALLINE ALUMINUM OXIDE.**

R.C.Folweiler.

J. appl. Phys. (USA), Vol. 32, No. 5, 773-8 (May, 1961).

Creep in pore-free polycrystalline aluminium oxide was studied as a function of temperature, grain size, and strain rate. The behaviour may be described by  $\sigma \propto d^{2/3}$ , where  $d$  is the mean grain diameter. Deformation is not controlled by basal slip but by a diffusional creep process as described by Nabarro (Abstr. 3514 of 1949) and Herring (Abstr. 5359 of 1950).

**7827 EXPERIMENTAL EVIDENCE OF ELECTRIC CHARGES IN IONIC CRYSTALS ALONG SLIP PLANES.**

H.Saucier and C.Dupuy.

C.R. Acad. Sci. (France), Vol. 252, No. 7, 1039-41 (Feb. 13, 1961). In French.

A xeroradiographic method (Abstr. 1899 of 1959) was used to show lines of charge on a strained MgO crystal. A.R.Stokes

**TEMPERATURE DEPENDENCE OF ROLLING TEXTURES IN HIGH-PURITY SILVER.** See Abstr. 7873

**A POSSIBLE MECHANISM OF FORMATION OF SLIP-LINES IN THE ABSENCE OF LOCALIZED SOURCES OF DISLOCATIONS.** See Abstr. 7581

**7828 MEASUREMENT OF THE TENSILE STRENGTH OF BRITTLE MATERIALS.**

A.Ormerod; R.Berenbaum and I.Brodie.

Brit. J. appl. Phys., Vol. 12, No. 1, 29-30, 30 (Jan., 1961).

It is suggested that the apparent discrepancy between experimental and calculations for the tensile strength of brittle materials (Berenbaum and Brodie, Abstr. 4546 of 1960) is due to the use of conventional formulae, to calculate the stress set up by the bending moment, which is inapplicable if the material does not adhere closely to Hooke's law. In an added note Berenbaum and Brodie accept the criticism but suggest that it does not abrogate the general thesis of the paper. R.F.Peart

**7829 HIGH STRENGTH GLASS.**  
D.G.Holloway and P.A.P.Hastilow.

Nature (GB), Vol. 189, 385-6 (Feb. 4, 1961).

Fibres of several commercial glasses, 350-700  $\mu$  diameter and free from visible surface defects (see Abstr. 21138 of 1960) were tested in three-point bending. Mean breaking strengths of about 250 kg/mm<sup>2</sup> were obtained. D.G.Holloway

**7830 SMOOTH SPALLS AND THE POLYMORPHISM OF IRON.** J.O.Erkman.

J. appl. Phys. (USA), Vol. 32, No. 5, 939-44 (May, 1961).

When Armco iron is loaded with a transient wave in which the pressure exceeds 0.131 megabar, smooth spalls may be observed. The two distinct compression shocks which are transmitted by the iron are followed by a steep rarefaction which may be called a rarefaction shock. At a free surface, the first compression shock is reflected as a backward-facing rarefaction wave. This wave may also steepen into a rarefaction shock which eventually meets the forward-facing rarefaction shock. The interaction of these waves results in a localized tension of destructive magnitude, which produces a smooth fracture. Location of the plane of this interaction was calculated by applying the theory of hydrodynamics. These calculations are inexact because the speed of sound for relief waves was taken from Hugoniot data since other data are not available. Fair agreement was obtained between experimental and calculated results. The work indicates that, in the case of a double spall, the fracture most remote from the original free surface may sometimes be formed first.

**7831 THE INFLUENCE OF ATMOSPHERIC CORROSION ON THE FATIGUE LIMIT OF IRON-0.5% CARBON.**

N.J.Wadsworth.

Phil. Mag. (GB), Vol. 6, 397-401 (March, 1961).

Iron-0.5% carbon was fatigued in air and in vacuum. The knee in the S-N curve at the fatigue limit occurred at about the same number of cycles in vacuum as in air but at a higher strain. Above this strain specimens lasted about ten times as long in vacuum as in air. Slip occurred in a similar manner above and below the fatigue limit and cracks formed in the slip bands in both cases. Below the fatigue limit the cracks grew a few microns long.

## STRUCTURE OF SOLIDS

**7832 ORDERING OF THE SECOND KIND PRODUCED IN AUSTENITE BY INTERMEDIATE TRANSFORMATION.**  
L.S.Palatnik and I.A.Tananko.

Dokl. Akad. Nauk SSSR, Vol. 133, No. 4, 821-4 (Aug. 1, 1960). In Russian.

For abstract, see Abstr. 18397 of 1960. [English translation in Soviet Physics-Doklady (USA), Vol. 5, No. 4, 881-3 (Jan.-Feb., 1961)].

**7833 PEASE TRANSITION IN AMMONIUM FLUORIDE.**  
R.Stevenson.

J. chem. Phys. (USA), Vol. 34, No. 1, 346-7 (Jan., 1961).

High pressure experiments on ammonium fluoride showed that at room temperature a phase change, accompanied by a volume change of about 28%, occurs at 3800 atm pressure. The transition pressure is almost the same for increasing and decreasing pressures at room temperature, but at liquid nitrogen temperature the pressure had to be removed completely for recovery to occur. At all temperatures the transition took several minutes for completion. At atmospheric pressure NH<sub>4</sub>F has the Wurtzite structure, and it is suggested that the pressure-induced transition is from this to a cubic structure, similar to those found in other halides. R.V.Coates

**7834 INTERDOMAIN SYMMETRY IN THE REVERSIBLE PHASE TRANSFORMATION OF POTASSIUM CYANIDE.**

A.Cimino and G.S.Parry.

Nuovo Cimento (Italy), Vol. 19, No. 5, 971-80 (March 1, 1961).

The orientation of domains in transformed single crystals of KCN is considered in detail by means of stereographic projections. It is shown how the elements of point group symmetry of the high-temperature phase divide on transformation into the intradomain symmetry elements that are preserved in the new crystal structure and the interdomain symmetry elements that relate individual domains possessing this new structure. A method of deriving the number of independent domain orientations is given in terms of these concepts and is applied to the alternative transformation schemes of KCN. Consideration is also given to the physical aspects of domain coexistence in KCN. The lattice changes which take place on transformation are considerable and it is shown that although "invariant" lattice planes common to two domain orientations do exist in some cases, such a continuous transformation mechanism cannot account for all the domain orientations observed experimentally and an earlier conclusion that discontinuous processes must also occur is confirmed.

**7835 ON THE POSSIBILITY OF GRADUAL PHASE TRANSITIONS IN SOLIDS.** J.W.Allen and D.M.Eagles.  
Physica (Netherlands), Vol. 26, No. 7, 492-500 (July, 1960).

In principle it is possible for some substances to change from one crystal structure at low temperature to a second structure at high temperature by way of a continuous range of mixed structures, the transition taking place over a range of temperatures. Some simple models are discussed to illustrate this possibility, and by considering the thermodynamics of the process, conditions are laid down which a system must obey in order to show this behaviour. A comparison of the predictions of the theory with some experimental results on zinc sulphide is presented.

**INFLUENCE OF SPIN ON ELECTRONIC TRANSFORMATIONS.** See Abstr. 7551

PHASES IN THE PHOTOELECTRIC SODIUM-POTASSIUM-ANTIMONY SYSTEM. See Abstr. 7677

LOW-TEMPERATURE TRANSFORMATIONS OF ICE. See Abstr. 7868

## CRYSTALLOGRAPHY

7836 CRYSTALS OF CELLULOSE.  
R.S.J.Manley.

Nature (GB), Vol. 189, 390-1 (Feb. 4, 1961).

Microscopic lamellar crystals of cellulose triacetate were obtained from a solution in nitromethane. They were converted to cellulose without disturbing the external form of the crystals although 30% shrinkage in the lateral dimensions occurred. X-ray diffraction indicates that the deacetylated material has the structure of cellulose II and that the reaction had occurred throughout the crystals and not merely on the surface. Optical birefringence observations suggest that the orientation of the chain molecules with respect to the layers was not changed by the deacetylation. It is probable that molecular chain folding occurs in cellulose as it does in other polymers.

J.Iball

7837 TWINNING AND DISLOCATIONS IN SINGLE-CRYSTAL SILICON. M.G.Mil'vidskii and L.V.Lainer.

Fiz. tverdogo Tela (USSR), Vol. 3, No. 1, 289-96 (Jan., 1961). In Russian.

The external twinning form of single crystal Si, grown along or near to the  $[111]$  and  $[110]$  directions by the Chokhralski technique, is investigated, and also the behaviour of dislocations in crystals with twinning, using etching techniques. The twin boundaries form barriers to the development of dislocations in the twinned regions. The possibility of the penetration of dislocations along slip bands through the twin boundaries is demonstrated experimentally. It is shown that the dislocation density in the twin is determined by two factors: (a) the concentration of dislocations penetrating through the twin boundary from the main crystal; (b) orientation of the slip system up to and after twinning relative to the direction of the basic temperature gradient in the growing crystal. [English translation in: Soviet Physics-Solid State (USA)].

R.F.S.Hearmon

7838 GROWTH TWINS IN INDIUM ANTIMONIDE.  
R.K.Mueller and R.L.Jacobson.

J. appl. Phys. (USA), Vol. 32, No. 3, 550-1 (March, 1961).

The preferential occurrence of twin boundaries in crystals grown in opposite directions along the  $\langle 110 \rangle$ ,  $\langle 111 \rangle$ , and  $\langle 211 \rangle$  axes is interpreted in terms of the polar nature of the zincblende lattice. The twins initiate where the  $\{111\}$  planes intersect the surface of the crystal and it is suggested that where the solid-liquid interface meets the surface tangentially to a  $\{111\}$  plane, two-dimensional nucleation of a twinned layer can occur. This is thought to be more likely when the  $\{111\}$  plane exposed is a B or  $\{1\bar{1}\bar{1}\}$  type.

W.Bardsley

7839 DEFORMATION TWINNING IN FACE-CENTRED CUBIC METALS. J.A.Venables.

Phil. Mag. (GB), Vol. 6, 379-96 (March, 1961).

The principal features of the experimental results of Blewitt et al. (Abstr. 423 of 1958), and of Suzuki and Barrett [Acta metallurgica (Internat.), Vol. 6, 156 (1958)] on deformation twinning in face-centred cubic metals are explained in terms of an extension of the "prismatic" source mechanism of Cottrell and Bilby (Abstr. 7376 of 1951). Suitable prismatic dislocation sources are thought to be long jogs in the dislocations of the two conjugate slip systems in a work-hardened metal and prismatic dislocation loops produced by vacancy condensation in a neutron-irradiated metal. The dissociation of slip dislocations is also considered and is found to be an unlikely mechanism for the production of deformation twins in copper, silver or gold.

7840 SOME NEW HABIT FEATURES IN CRYSTALS OF LONG CHAIN COMPOUNDS. I. PARAFFINS. A.Keller.

Phil. Mag. (GB), Vol. 6, 329-43 (March, 1961).

Habits of paraffin crystals were examined with the optical and electron microscope. In particular striations along different crystallographic directions were noticed which could be produced systematically by neat treatment. It was found that such striations

often corresponded to geometrically regular ridges. It is proposed that these ridges represent different phases within the crystals corresponding to structures of differing obliquities all based on the same subcell. Accordingly a variety of structures can be realized within the same crystal by different amounts of simple shear on different planes along the  $c$  direction where the shear, while regular, need not be uniform. A number of other less regular morphological features are also described.

7841 SOME NEW HABIT FEATURES IN CRYSTALS OF LONG CHAIN COMPOUND. II. POLYMERS.

D.C.Bassett and A.Keller.

Phil. Mag. (GB), Vol. 6, 345-58 (March, 1961).

The morphology underlying the characteristic striations observed in polymer crystals were examined in more detail than hitherto. The striations were found to correspond to corrugations in crystal layers. Both pleat and roof-ridge corrugations were observed in polyethylene crystals. These latter are pictorially similar to those in paraffin crystals discussed in Part I. The analogy between the two cases is pursued with the folds replacing the end groups in the polyethylene case. A possible common origin for both types of corrugation is proposed to be the collapse of non-planar crystals. A particular non-flat based pyramidal model is proposed. Direct evidence for the existence of such crystals is presented. A variety of observations, including the non-planar crystals, is shown to be explainable in terms of a particular type of packing of the folded molecular chains. Further, it is suggested that if folding also occurs in the bulk polymer, then roof ridges of the type discussed might account for its well-known four-point low-angle X-ray pattern.

SMOOTH SPALLS AND THE POLYMORPHISM OF IRON.

See Abstr. 7830

7842 MONDRIAN PRECIPITATION PATTERNS IN SINGLE CRYSTALS OF TITANIUM CARBIDE. W.S.Williams.

J. appl. Phys. (USA), Vol. 32, No. 3, 552-4 (March, 1961).

An account is given of etching studies made on large single crystals of titanium carbide. In agreement with the work of Gilman on lithium fluoride (Abstr. 13780 of 1959) it was found that the etch pits formed at precipitates are square and flat bottomed whereas those formed on dislocations have pyramidal shaped bottoms. After annealing at  $2000^{\circ}\text{C}$  in vacuo and slowly cooling, the carbon precipitates formed platelets along  $\{111\}$  planes. The pattern formed by these precipitates closely resembles the abstractions painted by the Dutch artist Piet Mondrian. An example of the artist's work is reproduced for comparison.

R.Bullough

7843 ETCH PITS AND DEHYDRATION NUCLEI ON CRYSTALS OF GYPSUM. J.E.Bright and M.J.Ridge.

Phil. Mag. (GB), Vol. 6, 441-4 (March, 1961).

A study was made of the development of etch pits and dehydration nuclei on the  $(010)$  face of crystals of gypsum. The etch pits marked the sites of features that extended into the crystals. Dehydration nuclei in general did not occur at the same sites etch pits. The nature of the sites favourable for the formation of etch pits and of dehydration nuclei is discussed.

7844 TECHNIQUE FOR THE CINEPHOTOGRAPHIC STUDY OF ETCHING PHENOMENA.

G.S.Tint and V.V.Damiano.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 325-7 (March, 1961).

A device was constructed to photograph, on motion picture film, the etching behaviour of zinc monocrystals. This apparatus consists of: (1) a transparent cell to hold sample and etchant; (2) a microscope with vertical illuminator; and (3) a motion picture camera driven by an electric motor. Several sequences of these pictures are reproduced, showing the continuous formation of spiral-like etch patterns.

7845 LAYER-SPIRAL GROWTH OF CRYSTALS.  
A.A.Chernov.

Uspekhi fiz. Nauk (USSR), Vol. 73, No. 2, 277-331 (Feb., 1961). In Russian.

A review with 144 references. The subject is dealt with under the following headings: Surface of a crystal in equilibrium with the surrounding medium; surface energy of crystals; growth of crystals from the vapour; growth of crystals from solution and the melt; interaction between growing crystals and impurities; etching.

R.F.S.Hearmon

## GROWTH AND DEFECTS IN CdS CRYSTALS.

See Abstr. 7574

## COBALT FERRITE SINGLE CRYSTALS.

7846 A. Ferretti, R. J. Arnott, E. Delaney and A. Wold.

J. appl. Phys. (USA), Vol. 32, No. 5, 905 (May, 1961).

A crystal of cobalt ferrite was grown from the melt at 1600°C under an oxygen pressure of 790 lb/in<sup>2</sup>. Chemical analysis of a portion of the crystal gave a ferrous ion content of 1.3%.

## GROWTH OF SINGLE-CRYSTAL IRON FERRITES BY THE CZOCHRALSKI METHOD. F.H. Horn.

7847 J. appl. Phys. (USA), Vol. 32, No. 5, 900-1 (May, 1961).

## PREPARATION OF HIGH-PURITY INDIUM ARSENIDE. D. Effer.

7848 J. Electrochem. Soc. (USA), Vol. 108, No. 4, 357-61 (April, 1961).

The purest indium arsenide so far reported has a carrier concentration of about  $1.3 \times 10^{16}$  electrons/cm<sup>3</sup> at room temperature. This is several times the intrinsic value and it has been suggested that the limiting impurity may be sulphur originating in the arsenic component. Arsenic was prepared by the thermal decomposition of highly purified arsine gas and was combined with samples of indium purified by a variety of processes. Mass spectrographic analysis of the resultant ingots showed in all cases a sulphur content less than 0.05 p.p.m. The purest sample has a Hall coefficient of 795 cm<sup>3</sup>/C at 77°K, corresponding to an electron concentration of  $8 \times 10^{15}$ /cm<sup>3</sup> while the Hall mobility was 75700 cm<sup>2</sup> V<sup>-1</sup> sec<sup>-1</sup>. Analytical techniques failed to detect the prime source of the free electron concentration, but it is concluded that sulphur is not the dominant impurity in these samples.

## APPARATUS FOR CRYSTALLIZING SILICON WITHOUT USING A CRUCIBLE.

7849 Ya. E. Pokrovskii and V. B. Dik.

Pribery i Tekh. Eksper. (USSR), 1958, No. 1, 140-1 (Jan.-Feb.).

[English translation in: Instrum. exper. Tech. (USA), No. 1, 156-7 (Jan.-Feb., 1958; publ. April, 1958)].

## SIMPLE WET-STRING CRYSTAL CUTTER.

7850 C. N. Fallier, Jr.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 342-4 (March, 1961).

A simple, automatic wet-string cutter for rapid cutting of water soluble crystals is described. The instrument, assembled from commercially available components, is provided with a microscope stage and rotating vernier scale for accurately positioning the specimen to be sliced. Interchange of crystals is simple and rapid.

## APPARATUS FOR GROWING VERY PURE SINGLE GERMANIUM CRYSTALS.

7851 V. B. Dik and V. V. Ostroborodova.

Pribery i Tekh. Eksper. (USSR), 1958, No. 1, 142-3 (Jan.-Feb.).

[English translation in: Instrum. exper. Tech. (USA), No. 1, 158-9 (Jan.-Feb., 1958; publ. April, 1958)].

## STUDY OF THE SEGREGATION OF SILVER IN TIN DURING THE PROCESS OF ZONE MELTING.

7852 R. Reich and F. Montariol.

C.R. Acad. Sci. (France), Vol. 252, No. 1, 122-4 (Jan. 4, 1961). In French.

With radioactive silver, the non-uniform distribution of the silver after a zone pass is shown up on an autoradiograph of the tin ingot. By using a stabilized zone, the silver is uniformly distributed. The distribution coefficient of silver in dilute solution is calculated from measurements on a uniform bar. The values obtained show that a stabilized zone has an efficiency approaching the theoretical value.

W. Bardsley

## STABILITY OF PRESSURE-SUPPORTED MOLTEN ZONES IN HORIZONTAL SHEETS.

7853 H. P. Kramer, B. P. Bogert and D. W. Hagelbarger.

J. appl. Phys. (USA), Vol. 32, No. 5, 764-8 (May, 1961).

It is shown that the stability limit for pressurized horizontal floating zones is related to the eigenvalues of a membrane of the same shape. In particular, a rectangle of length  $a$  and width  $b$  is stable if  $\pi^2(a^2 + 1/b^2) \geq \rho g/\gamma$ , and a circle of radius  $R$  is stable if  $(\beta_{11}/R)^2 \geq \rho g/\gamma$ , where  $\rho$  is the density,  $g$  is the acceleration of gravity,  $\gamma$  is the surface tension constant, and  $\beta_{11} = 3.8317$  is the first root of the Bessel function  $J_1(x)$ . This latter case checks with experiments on melted circular zones of tin.

VACUUM RADIATION FURNACE WITH PRECISE CONTROL OF TEMPERATURE GRADIENTS FOR CRYSTAL GROWTH BY SUBLIMATION. See Abstr. 6984

## GROWTH OF LITHIUM HYDRIDE SINGLE CRYSTALS.

See Abstr. 7697

## ON THE GROWTH OF SAPPHIRE MICROCRYSTALS.

7854 C. M. Hargreaves.

J. appl. Phys. (USA), Vol. 32, No. 5, 936-8 (May, 1961).

Thermodynamical considerations on the vapour-phase growth of whisker and platelet crystals of  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> by the oxidation of aluminium lead to the conclusion that the vapour-phase mass transport is probably due to the suboxide Al<sub>2</sub>O and not AlO as previously suggested. Electron microscope observations confirm the optical evidence that spiral growth steps do not occur on the (0001) surfaces of Al<sub>2</sub>O<sub>3</sub> crystals grown in this way.

## UNIVERSAL STAGE ACCESSORY FOR DIRECT DETERMINATION OF THE THREE PRINCIPAL INDICES OF REFRACTION. R. E. Wilcox.

7855 Amer. Mineralogist, Vol. 44, 1064-7 (Sept.-Oct., 1959).

## USE OF THE SPINDLE STAGE FOR DETERMINATION OF PRINCIPAL INDICES OF REFRACTION OF CRYSTAL FRAGMENTS. R. E. Wilcox.

7856 Amer. Mineralogist, Vol. 44, 1272-93 (Nov.-Dec., 1959).

A small crystal or crystal fragment mounted on the tip of a spindle in a suitable holder on the polarizing microscope stage may be oriented quickly and accurately for measurement of all its principal indices of refraction by the immersion method. Independent measurements or estimations of other properties, such as optic angle, optic sign, dispersion, pleochroism, and the relation of the indicatrix to cleavage or crystal faces may be made on the same fragment.

## CRYSTAL LATTICE STRUCTURES

## LIGHT-OPTICAL ANALOGS OF X-RAY DIFFRACTION PATTERNS. J. R. Meyer-Arendt and J. K. Wood.

7857 Amer. J. Phys., Vol. 29, No. 6, 341-4 (June, 1961).

Masks containing repeating arrays of holes were prepared to simulate the molecular structure of arbitrary crystals. These masks, after photographic reduction, were used for Fraunhofer-type light diffraction and the resulting diffraction patterns compared with X-ray diagrams. This procedure was evaluated from two points of view: (1) it facilitates the teaching of fundamental processes of X-ray diffraction, and (2) it shows that terms like "regularity" or "randomness" of the arrangement of crystallites apply to at least two different levels of organization: The structure of individual crystallites and the distribution and/or orientation of different crystallites relative to each other.

## EFFECT OF LONG WAVELENGTH HARMONICS ON DOUBLE CRYSTAL DIFFRACTOMETER MEASUREMENTS. B. W. Batterman.

7858 Rev. sci. Instrum. (USA), Vol. 32, No. 4, 393-6 (April, 1961).

It is shown that large errors due to long wavelength harmonics can occur in the determination of integrated intensities and half-widths with a double crystal spectrometer. For example, in measuring the integrated intensity of the (333) reflection of silicon with Mo K $\alpha$  radiation, an error of a factor of 4 is possible due to 3 $\lambda$  radiation from the white spectrum which is simultaneously diffracted by the (111) planes. The amount of error is dependent upon the particular experimental arrangement (tube voltage and allowed horizontal divergence being the most important factors), and can be reduced, and in most cases eliminated, by use of an appropriate filter.

## X-RAY DETERMINATION OF CRYSTAL STRUCTURES. P. B. Braun and A. J. van Bommel.

7859 Philips tech. Rev. (Netherlands), Vol. 22, No. 4, 126-38 (1960-61).

Discussion of the principles and some applications of structure determinations by X-ray diffraction. The electron density in a crystal can be determined by Fourier summations of "density waves". The amplitude, wavelength and direction of these component waves are deduced directly from the X-ray diffraction pattern. The main problem is to determine the phase of the density waves. These are

calculated with the aid of provisional models of the crystal structure. Patterson's method is useful here, providing information on interatomic distances. Various structure determinations are described. It is indicated how knowledge of the structure so found can be of great help in understanding the properties of the substances investigated, in the examples given the gettering properties of  $\text{Th}_2\text{Al}$ , and the magnetic properties of the compound  $\text{Al}_{0.89}\text{Mn}_{1.11}$  and of  $\text{Y-Ba}_2\text{Zn}_2\text{Fe}_{12}\text{O}_{22}$  (one of the ceramic magnetic materials of the "ferroxplana" group).

7860 "PACKING RELATIONS" AND CRYSTALLINE STRUCTURE. J.D.H. Donnay and G. Donnay. C.R. Acad. Sci. (France), Vol. 252, No. 6, 908-9 (Feb. 6, 1961). In French.

Accidental extinctions of X-ray diffraction reflections, taken with the systematic absences of the space-group for the faces of a zone normal to a symmetry plane, indicate, when projected onto the symmetry plane, the existence of any sub-multiple cell, or pseudo-cell and the true cell. As an example, the (0kl) reflections of columbite,  $(\text{FeNb}_2\text{O}_6)_n$ , are considered, and it is shown that the theory leads to the same choice of atomic positions in the cell as those determined by Sturdivant. R.V. Coates

7861 METHOD OF MOMENTS IN ANALYSIS OF X-RAY DIFFRACTION LINES. A. Fingerland. Czech. J. Phys., Vol. 10, No. 3, 233-9 (1960).

A general relation between the moments of the functions  $f$ ,  $g$ , and  $h$ , in the equation

$$h(x) = \int f(y) g(x-y) dy,$$

is derived. This enables any moment of the unknown function  $f$  to be calculated from the moments of the functions  $g$  and  $h$ . In particular, if certain assumptions are fulfilled, the moments of the components of the doublet can be calculated with advantage from the moments of the total profile. The statistical significance of the moment characteristics is also emphasized.

7862 RAPID GRAPHICAL DETERMINATION OF THE RADIAL INTENSITY DISTRIBUTION OF THE SMALL-ANGLE SCATTERING OF X-RAYS FROM THE MEASURED DATA. V. Synček and M. Simerská. Czech. J. Phys., Vol. 10, No. 3, 240-6 (1960).

The radially symmetrical small-angle scattering pattern (which would be obtained by the use of a direct beam having a point-like cross-section) is in practice distorted, especially by the beam height. To eliminate this distortion the integration of a set of curves based on the derivative of the measured intensity distribution is required to derive the true radial intensity distribution. A rapid graphical method of plotting these curves is described and its accuracy is proved on an example. It is further shown that the radial intensity distribution can be determined in principle using the values of the measured curve instead of its derivative.

7863 DETERMINATION OF THE PHASES OF STRUCTURE AMPLITUDES FROM A MODIFIED MINIMALIZATION FUNCTION. V.I. Simonov. Dokl. Akad. Nauk SSSR, Vol. 136, No. 4, 813-16 (Feb. 1, 1961). In Russian.

A theoretical paper discussing and developing the application of minimalization functions, including their use with digital computers. R.F.S. Hearmon

X-RAY ATOMIC SCATTERING FACTORS OF Fe, Cu AND Al. See Abstr. 7433

7864 STUDY OF THE CRYSTALLINE STRUCTURE OF THIN FILMS OF NICKEL BY ELECTRON DIFFRACTION. C. Bonnelle and F. Jacquot. C.R. Acad. Sci. (France), Vol. 252, No. 10, 1448-50 (March 6, 1961). In French.

Thin films of nickel evaporated at a controlled rate on to collodion films and on to suitably prepared nickel substrates were subsequently heated to about  $600^\circ\text{C}$  and the growth of a close-packed hexagonal structure observed by electron diffraction. The observations are discussed with reference to other work and the influence of the structure before heating is noted. The atmospheres were air or argon at pressures of  $3$  to  $7 \times 10^{-5}$  mm Hg. T.C. Toye

7865 THE DISTRIBUTION OF ELECTRON DENSITY IN INDIUM ARSENIDE. N.N. Sirota and N.M. Olekhovich. Dokl. Akad. Nauk SSSR, Vol. 136, No. 3, 660-2 (Jan. 21, 1961). In Russian.

Using copper  $K\alpha$  radiation, X-ray spectrograms were obtained from powdered InAs, and lines with certain types of indices  $h, k, l$ , were used to calculate values of the square of the structure amplitude  $F^2$ . The atomic scattering factors of In and As, and their logarithms were also calculated. Graphs of these three sets of quantities plotted against  $\Sigma h_i^2$  are exhibited and discussed. The distribution of electron density was calculated from the values of the two atomic scattering factors by the method of summation of a three-dimensional Fourier series described earlier. A map shows the distribution of electron density in InAs in the (110) plane, in a unit cell, and a set of graphs represents the distribution of electron density between the In and As ions in the [111] and [113] directions in the (110) plane. A curious "bridge" of electron density, i.e. a ridge of locally higher density, is found to exist in certain directions. This does not occur in Ge. [English translation in: Soviet Physics—Doklady (USA)]. N. Davy

7866 CRYSTAL STRUCTURE OF SILICON CARBIDE OF 174 LAYERS. T. Tomita. J. Phys. Soc. Japan, Vol. 15, No. 1, 99-105 (Jan., 1960).

A new modification of silicon carbide crystal, with rhombohedral symmetry and a unit cell composed of 174 layers, was found by X-ray study. The cell size and symmetry were determined as in a previous study of silicon carbide of 594 layers (Abstr. 8336 of 1950). The structure, namely the stacking order of Si-C layers, of the new modification, was determined by comparing the visual intensity with those calculated for a number of models. The structure is represented as  $\{C(\text{CCH})_7\text{C}_3(\text{CCH})_{11}\} \times 3$  by Wyckoff's notation (1948).

7867 X-RAY CORRELATION OF THE A-B LAYER ORDER OF CADMIUM SELENIDE WITH THE SIGN OF THE POLAR AXIS. R. Zare, W.R. Cook, Jr and L.R. Shiozawa. Nature (GB), Vol. 189, 217-19 (Jan. 21, 1961).

Reports the application of the effects of anomalous X-ray dispersion on the intensity of the X-rays reflected from the positive and negative sides of the basal plane in a wurtzite structure. The cadmium and selenium sides of the c-axis have thus been identified. The cadmium side was found to become positively charged on extension. Other differentiating properties were correlated to the piezoelectric sign. W. Bardsley

7868 ELECTRON DIFFRACTION STUDY OF ICE. K. Shimaoka. J. Phys. Soc. Japan, Vol. 15, No. 1, 106-19 (Jan., 1960).

Temperature ranges of formation of low-temperature forms of ice and the hydrogen position in cubic and hexagonal forms were studied by electron diffraction. The ranges were found to vary according to the rate of condensation of water vapour and the discrepancies between the previous data for the ranges were attributed to differences of this rate. Intensity of Debye-Scherrer patterns showed best agreement with Pauling's half-hydrogen model for cubic ice as well as for hexagonal ice. Difference radial distribution and two-dimensional difference Fourier analysis of cubic ice revealed also that Pauling's model is appropriate. From two-dimensional difference Fourier map of three different projections, O-H distance was found to be  $0.96 \pm 0.03$  Å. By calculation, it was shown that a shift of electron cloud causes no appreciable shift of potential peak. An elliptical elongation of hydrogen peak perpendicular to O-H bond was observed, which can be attributed to a shift of H-O-H angle from the tetragonal angle as well as to anisotropic thermal vibration.

7869 A NEW FORM OF NICKEL NITRIDE:  $\text{Ni}_4\text{N}$ . N. Terao. J. Phys. Soc. Japan, Vol. 15, No. 2, 227-30 (Feb., 1960). In French.

The transformation of nickel lattices under the influence of nitrogen as an insertion impurity was followed by electron diffraction after nitriding thin monocrystalline evaporated films of nickel in an atmosphere of ammoniac at different temperatures. The nitriding process occurs as follows:  $\text{Ni}(\text{f.c.c.}, a = 3.52) \rightarrow \text{Ni}_4\text{N}(\text{f.c.c.}, a = 3.72 \text{ Å}) \rightarrow \text{Ni}_3\text{N}(\text{hexagonal})$ . In this work, a detailed study of some anomalous diffraction spots reported, but not interpreted in a previous work (see Abstr. 10397 of 1959), was undertaken. It was found that these anomalous diffraction spots

appear rather clearly on the specimens nitrided at 230-240°C and they belong to a new form of  $Ni_4N$  which is no longer cubic but tetragonal. Its lattice parameters are:  $a = b = 3.72 \text{ \AA}$ ;  $c = 2c^* = 7.28 \text{ \AA}$ . These interpretations provide evidence of existence of two forms of  $Ni_4N$ : one cubic:  $Ni_4N(I)$  and the other, tetragonal:  $Ni_4N(II)$ . The tetragonal form  $Ni_4N(II)$  is derived from the cubic form  $Ni_4N(I)$ . This occurs as follows: Two elementary lattices of cubic  $Ni_4N(I)$  join together after contraction along  $[c]$  axis (from  $c = 3.72 \text{ \AA}$  to  $c^* = 3.64 \text{ \AA}$ ) and form a unit cell of the tetragonal form. The two other axes  $[a]$  and  $[b]$  conserve their initial value of  $3.72 \text{ \AA}$  ( $c^*/a = 0.98$ ).

7870 CRYSTAL STRUCTURE OF  $Ba_{0.5-x}TaO_{3-x}$ .  
F. Galasso and L. Katz.

Nature (GB), Vol. 188, 1099-1100 (Dec. 24, 1960).

$Ba_{0.5}TaO_3$  has a tetragonal-bronze structure. A trial structure for the reduced form of this material,  $Ba_{0.44}TaO_{2.94}$  has been determined. The reduced phase was produced only when the tantalum pentoxide came from a certain source unless barium chloride was used as a flux. Preparations obtained when using a flux were not homogeneous, and therefore no accurate density value was measured. The reduced phase has the same cell size and structure as the oxidized phase. X-ray single crystal photographs were obtained using  $Mo K\alpha$  radiation and a Buerger precession camera. Approximate co-ordinates are given. This trial structure has several disturbing features: (i) there are marked deviations from Pauling's electrostatic valence rules; (ii) the observed fixed ratio of Ba/Ta equals  $\sim 0.44$  is unexplained; (iii) there are only 18 oxygens occupying 24 available positions; (iv) the X-ray density is lower than the range measured.

R.V. Coates

STRUCTURE OF CELLULOSE II CRYSTALS. See  
Abstr. 7836

## ALLOYS . METALLURGY

7871 INTERNATIONAL CONFERENCE ON PLUTONIUM  
METALLURGY. E. Zimmer.

Energia nucleare (Italy), Vol. 7, No. 10, 685-90 (Oct., 1960). In Italian.

The international Conference on Plutonium Metallurgy, organized by the "Société française de métallurgie" and the "Commissariat à l'énergie atomique", was held at Grenoble in April, 1960. Plutonium physical properties, alloys, ceramic materials and nuclear fuels were dealt with on this occasion. An account of the papers delivered at the Conference is given.

7872 CHANGE IN PRIMARY EXTINCTION DURING  
DECOMPOSITION OF SUPERSATURATED SOLID  
SOLUTION. II. Al-Cu 4% ALLOY-FORMATION OF G.P. ZONES.  
K. Toman.

Czech. J. Phys., Vol. 10, No. 3, 208-14 (1960).

For Pt I, see Abstr. 3266 of 1961. The change in integrated intensity of the (200) reflections of a solid solution during the formation of G.P. zones was measured and compared with the change in the character of the diffuse streaks corresponding to them. It was found that the formation of G.P. zones does not lead to a decrease in primary extinction despite the great changes in the distribution of the copper atoms. It was shown that the formation of a precipitate accompanied by the formation of crystallographically incoherent boundaries greatly decreases the primary extinction.

7873 TEMPERATURE DEPENDENCE OF ROLLING TEXTURES IN HIGH-PURITY SILVER.

Hsun Hu and R.S. Cline.

J. appl. Phys. (USA), Vol. 32, No. 5, 760-3 (May, 1961).

A rolling texture transition from the  $(110)[\bar{1}12]$  common silver type to the  $(123)[\bar{1}\bar{1}2]$  copper type was produced in high-purity silver by changing the temperature of deformation. The texture determined at 0°C for a strip rolled at 0°C was a simple  $(110)[\bar{1}12]$ . Rolling at 200°C produced a texture of the  $(123)[\bar{1}\bar{1}2]$  type, plus a cube texture component due to partial recrystallization. The results also suggest that the relatively high oxygen content in common silver is probably not responsible for the formation of the  $(110)[\bar{1}12]$  texture. The change in texture from one type to the other in high-purity silver can be obtained by merely varying the rolling temperature.

7874 MARTENSITIC TRANSFORMATIONS IN THE  
TITANIUM--ZIRCONIUM SYSTEM.

V.N. Gridnev, V.I. Trefilov and V.N. Minakov.

Dokl. Akad. Nauk SSSR, Vol. 134, No. 6, 1334-6 (Oct. 21, 1960). In Russian.

For abstract, see Abstr. 4064 of 1961. [English translation in: Soviet Physics - Doklady (USA), Vol. 5, No. 5, 1094-6 (March-April, 1961)].

7875 THE KINETICS OF MOVING PHASE BOUNDARIES IN  
FERROMAGNETIC, FERROELECTRIC AND SUPER-  
CONDUCTING MATERIALS. A.C. Sim.

J. Electronics and Control (GB), Vol. 10, No. 2, 97-116 (Feb., 1961).

Models which ignore the thickness and properties of the boundary are generally invalid, and a correct analysis of the physics is made. New results are formulae for the wall thickness, and solutions for the cases of ferromagnetic insulators and ferrites. In the case of superconductors, the error in the usual theory could account for the departures from observation.

DIRECTIONAL ORDER PRODUCED BY TENSION IN A 50-50  
Ni-Co ALLOY. See Abstr. 7745

A THEORY OF SCATTERING OF X-RAYS BY DOMAIN  
STRUCTURES. V.M. Danilenko.

Fiz. Metallov i Metallovedenie (USSR), Vol. 10, No. 1, 3-8 (July, 1960). In Russian.

Scattering of X-rays by solid solutions with domain structures (anti-phase domains in ordered alloys, stacking faults, modulated structures) is analytically studied. It is concluded that the geometry of the diffracted beams is independent of the nature of the domain structure which, however, affects the intensity of both normal diffraction and diffusion phenomena. In the case of a periodic domain structure, X-rays are diffracted not only according to the Wolf-Bragg law, but also in several additional directions. When the structure loses its periodicity, broadening or splitting of normal diffraction can take place. A general formula describing the intensity of scattering of X-rays by any given domain structure is derived.

M.H. Sloboda

INTERMETALLIC COMPOUNDS BETWEEN  
7877 LANTHANONS AND TRANSITION METALS OF THE  
FIRST LONG PERIOD. I. PREPARATION, EXISTENCE AND  
STRUCTURAL STUDIES. K. Nassau, L.V. Cherry and W.E. Wallace.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 123-30 (Nov., 1960).

Alloys were prepared with compositions corresponding to the formulas  $AB_3$ ,  $AB_2$ ,  $AB$  and  $A_3B$ , in which A is Y, La, Ce, Sm, Gd, Dy or Ho and B is Mn, Fe, Co or Ni. Samples were prepared by the technique of levitation melting. Powder diffraction patterns were obtained to establish whether or not the various alloys existed in the form of intermetallic compounds. Extensive compound formation tendency was exhibited by all the lanthanons except La. All  $AB_2$  type compounds were found to exist in the  $MgCu_2$  structure. The  $AB_3$  type compounds occurred either in the  $CaCu_5$  structure or in an unsolved orthorhombic structure. Some  $AB$  and  $A_3B$  compounds may exist. Confirmation awaits interpretation of their diffraction patterns. Factors affecting the existence of these compounds and their structural parameters are discussed.

EFFECTS OF SOLID SOLUTION OF  $Ga_2Te_3$  WITH  
7878  $As^{IV}Bi^{VI}$  TELLURIDES. J.C. Woolley and B. Ray.

J. Phys. Chem. Solids (GB), Vol. 16, No. 1-2, 102-6 (Nov., 1960).

Alloys were produced for the three systems  $Ga_2Te_3$ -ZnTe,  $Ga_2Te_3$ -CdTe and  $Ga_2Te_3$ -HgTe and annealed to obtain equilibrium conditions. The ranges of solid solution, the variation of lattice parameter with composition and the ranges and types of ordering which occur were investigated. For the system  $Ga_2Te_3$ -ZnTe, the variation of optical energy gap  $E_g$  with composition was determined by infrared transmission measurements.

STUDY OF THE SEGREGATION OF SILVER IN TIN  
DURING THE PROCESS OF ZONE MELTING. See Abstr. 7852

## OTHER SOLID FORMS

HIGH STRENGTH GLASS. See Abstr. 7829

7879 THE APPARENT SECOND-ORDER TRANSITION OF HIGH POLYMERS WITH SPECIAL EMPHASIS ON ITS MANIFESTATION IN THE MECHANICAL PROPERTIES. T.Hideshima.

Suppl. Progr. theor. Phys. (Japan), No. 10, 174-97 (1959).

"Relaxation phenomena of polymers" meeting, Kyoto, 1958 (see Abstr. 6449 of 1961). A general phenomenological analysis of the nature of the apparent second-order transition of high polymers is made. The effect of the transition on mechanical properties is discussed with experimental comparisons. Some requirements for a molecular theory are also presented.

7880 SINTERING CRYSTALLINE SOLIDS. I. INTERMEDIATE AND FINAL STATE DIFFUSION MODELS. R.L.Coble.

J. appl. Phys. (USA), Vol. 32, No. 5, 787-92 (May, 1961).

Photomicrographs of pore and grain boundary structures in sintered powder compacts are presented to provide the basis for qualitative description of the important phases of the course of densification. From this guide, appropriate grain shapes and pore shapes and locations are selected for the formulation of diffusion sintering models. The principle models presented are for bulk diffusion transport with the grain boundaries as vacancy sinks when the pore phase is continuous and coincident with three grain edges, and also when the pore phase is discontinuous and located at four-grain corners. These models predict that the rate of density change is constant when the diffusion coefficient and grain size are constant. The need for simultaneous isothermal densification and grain growth data is indicated. The explicit change in densification rate with discontinuous grain growth is predicted in terms of pore spacing and grain size.

7881 SINTERING CRYSTALLINE SOLIDS. II. EXPERIMENTAL TEST OF DIFFUSION MODELS IN POWDER COMPACTS. R.L.Coble.

J. appl. Phys. (USA), Vol. 32, No. 5, 793-9 (May, 1961).

During sintering in alumina powder compacts, the density was found to increase linearly with the logarithm of time, and the grain size increases with the one-third power of time. Incorporation of the time dependence of grain size increase into late-stage bulk diffusion sintering models (see preceding abstract) leads to corrected models by which a semilogarithmic behaviour is predicted. The presence of density gradients in normally fabricated pellets makes impossible the deduction of whether theoretical density will be achieved from the early stages of the course of densification. Diffusion coefficients calculated from the intermediate and later stages of sintering bear order-of-magnitude agreement with those calculated from the initial-stage sintering measurements in alumina. All diffusion coefficients from sintering data are higher than Kingery's measured diffusion coefficients for oxygen. It is hypothesized that the sintering process must then be controlled by bulk diffusion of aluminium ions while the oxygen transport takes place along the grain boundaries. In controlling the sinterability of alumina to theoretical density, it appears that magnesia does not "inhibit" discontinuous grain growth, but instead increases the sintering rate such that discontinuous growth nuclei do not have time to form.

SAMPLING OF SUB-MICRON PARTICLES FOR ELECTRON MICROSCOPY. See Abstr. 7895

7882 TORTUOSITY IN POROUS MEDIA. P.B.Lorenz.

Nature (GB), Vol. 189, 386-7 (Feb. 4, 1961).

A qualitative explanation is given for the fact that the relationship between porosity and formation factor of a porous medium is different when it is derived from permeability experiments instead of from measurement of electrical migration and diffusion.

R.Schnurmann

## Surfaces . Films . Adsorption

7883 USE OF HELIUM FLUSH IN THE VACUUM DEPOSITION OF THIN FILMS. G.N.Srivastava and G.D.Scott.

Brit. J. appl. Phys., Vol. 12, No. 5, 255-6 (May, 1961).

Silver films deposited in a vacuum chamber previously flushed with an inert gas, helium, exhibit less aggregation as shown in electron micrographs and reduced ageing as determined from electrical conductivity, as compared with films produced under the usual high vacuum procedures. It is concluded that in general flushing the vacuum chamber with helium is of value in producing stable, compact and pure evaporated films.

7884 PREPARATION OF THIN FILMS OF GALLIUM BY VACUUM EVAPORATION. S.Martinuzzi.

C.R. Acad. Sci. (France), Vol. 252, No. 9, 1314-16 (Feb. 27, 1961). In French.

Gallium films evaporated in vacuum have a metallic appearance up to a thickness of 25 mμ and then become covered with a greyish powdery film. This is caused by subcooling (Abstr. 223 of 1950) and can be avoided by evaporation on to a substrate cooled by liquid nitrogen.

V.J.Hammond

7885 PROPERTIES OF THIN ANTIMONY FILMS DEPOSITED IN HIGH VACUUM. G.A.Condas and F.O.Wooten.

J. appl. Phys. (USA), Vol. 32, No. 2, 323-4 (Feb., 1961).

Antimony evaporated at pressures of  $10^{-9}$  torr and lower with deposition rates as low as 0.1 - 1 Å/sec was shown to produce homogeneous metallic films while films of comparable quality when evaporated at higher pressures were only produced by increasing the rate of deposition. Pressures higher than  $10^{-7}$  torr required a rate of more than 100 Å/sec. It is suggested that the residual atmosphere was the principal cause of the formation of heterogeneous films particularly due to the possible inclusions of oxides formed by the reaction of antimony with the residual water vapour always present in unbaked vacuum systems.

W.Steckelmacher

7886 TEXTURAL PROPERTIES OF GERMANIUM FILMS. J.E.Davey.

J. appl. Phys. (USA), Vol. 32, No. 5, 877-80 (May, 1961).

The textural properties of thin germanium films vacuum evaporated onto hot fused-quartz substrates were investigated in detail over the temperature range from ambient to 650°C. The strongest texture characteristic of these films is the [110], which is obtained at substrate temperatures as low as 175°C, and prevails up to about 350°C. For temperatures between 350°C and 575°C, competition for growth occurs and the texture varies principally between being powder, [110] and [111]. Above 575°C the [111] texture becomes dominant.

OPTICAL PROPERTIES AND STRUCTURE OF THIN FILMS OF SILVER. See Abstr. 7700

INFLUENCE OF THE RATE OF FORMATION OF THIN FILMS OF SILVER, OBTAINED BY THERMAL EVAPORATION, ON THEIR TRANSMISSION AND REFLECTION FACTORS. See Abstr. 7701

CRYSTALLINE STRUCTURE OF THIN FILMS OF NICKEL BY ELECTRON DIFFRACTION. See Abstr. 7864

A SIMPLE ELECTROLYTIC METHOD FOR PREPARING THIN METAL FOILS. See Abstr. 7891

7887 INTERACTION POTENTIALS OF SIMPLE NONPOLAR MOLECULES WITH GRAPHITE.

A.D.Crowell and R.B.Steele.

J. chem. Phys. (USA), Vol. 34, No. 4, 1347-9 (April, 1961).

The interaction and zero-point energies of Ne, Ar, Kr, Xe, and CH<sub>4</sub> molecules near a semi-infinite graphite lattice at the potential minimum are calculated using lattice sums of a (6-12) potential with empirically determined potential constants and compared with recent experimental data. The significance of the results with respect to the possible role of charge-transfer no-bond mechanism for these systems is briefly discussed and it is concluded that dispersion forces alone are sufficient to account for the interaction energy.

# MICROSTRUCTURE EXAMINATION

(By X-rays and Electron and Other Microscopes)

- 7888 VARIANT IN TECHNIQUE FOR A.R. LANG'S X-RAY DIFFRACTION TOPOGRAPHY.**  
H.A. Carlson and H.A.R. Wegener.  
J. appl. Phys. (USA), Vol. 32, No. 1, 125-6 (Jan., 1961).  
In the method described by Lang [Acta metallurgica, Vol. 5, 358 (1957); and Abstr. 1587 of 1960], for obtaining diffraction images of crystals, a point X-ray source and a moving crystal were used. A method is now described in which use of a line source of X-rays avoids the necessity of moving the crystal during the exposure, with the advantage that exposure time is reduced in roughly inverse proportion to the width of the source. On the other hand, the spacing of the crystal from the recording film must now be larger and precautions taken to eliminate  $K\beta$  radiation from the beam. Diffraction "topographs" are reproduced of a silicon crystal 0.9 mm thick, taken before and after decoration with copper. The exposure time in molybdenum  $K\alpha$  radiation (50 kV and 20 mA) varies from 1-24 hr, according to the recording emulsion employed.  
V.E. Cosslett
- 7889 STUDY OF X-RAY LINE-BROADENING DUE TO PLASTIC DEFORMATION IN FACE-CENTRED CUBIC METALS.** T.R. Anantharaman.  
Indian Institute of Science Golden Jubilee Research Volume (see Abstr. 2678 of 1961) p. 280-91.  
It is shown that the contribution of stacking faults to X-ray line-broadening in face-centred cubic metals is too large to be ignored in the formulation of any theory concerning the effects of plastic deformation on X-ray diffraction from metal powders. A systematic method of measuring and analysing X-ray line breadths in Debye-Scherrer patterns of face-centred cubic metals and alloys in the annealed and cold-worked states is developed to obtain information on the roles of small particle size, microstresses and stacking faults in X-ray diffraction phenomena associated with plastically strained metallic aggregates. The pure diffraction broadening in cold-worked nickel powder and copper filings is analysed in accordance with the suggested scheme and it is inferred that microstresses and stacking faults alone contribute to X-ray line-broadening in these two cases.
- 7890 SMALL-ANGLE SCATTERING IN GOLD-NICKEL ALLOYS.** G. Nagorsen and B.L. Averbach.  
J. appl. Phys. (USA), Vol. 32, No. 4, 688-9 (April, 1961).  
X-ray small-angle scattering observed in gold-nickel solid solutions is shown to arise from double Bragg reflections and to be unrelated to "critical scattering" associated with fluctuations in short-range order.
- 7891 A SIMPLE ELECTROLYTIC METHOD FOR PREPARING THIN METAL FOILS FOR DIRECT EXAMINATION IN THE ELECTRON MICROSCOPE.**  
N. Azam, M. Bouleau and P.A. Jacquet.  
C.R. Acad. Sci. (France), Vol. 252, No. 5, 698-700 (Jan. 30, 1961). In French.  
Ribbons of metal and alloys, including U and Zr, may be thinned using a manually operated cathode. The latter is the end of a Ni wire, 1 mm diameter, helically wound on a glass tube, which is swept over the ribbon contained in the electrolyte until a lacework pattern of holes is visible. Since low current intensities, 20-80 mA/cm<sup>2</sup>, are used, foil breakage is minimized.  
R. Reed
- 7892 TRANSMISSION ELECTRON MICROSCOPY OF ALNICO V.** J.M. Capenos and B.R. Banerjee.  
J. appl. Phys. (USA), Vol. 32, No. 2, 323 (Feb., 1961).  
A new technique for obtaining thin foils of brittle alloys, using

mechanical grinding followed by electrolytic polishing, is described. In foils of Alnico V, changes in the orientation of the Widmanstätten precipitate following heat treatment are clearly seen.  
R. Reed

- A HIGH TEMPERATURE DIFFRACTION ADAPTOR FOR THE RCA EMU-2A ELECTRON MICROSCOPE.**  
7893 K. Bahadur and P.V. Sastry.  
J. sci. industr. Res. (India), Vol. 19A, No. 3, 129-32 (March, 1960).  
With this arrangement it is possible to raise the temperature of the specimen to about 800°C in about 15 min. To illustrate the working of this adaptor, the work of Germer et al. (Abstr. 2399 of 1942) on order in Cu<sub>3</sub>Au alloy films at various temperatures was repeated and confirmed.
- 7894 SIMPLE METHODS FOR PREPARING POINTED FILAMENTS FOR THE ELECTRON MICROSCOPE.**  
D.E. Bradley.  
Nature (GB), Vol. 189, 298-300 (Jan. 28, 1961).  
Briefly describes a method for grinding a point on the tip of an electron microscope filament using a rotating disk of emery paper. Such filaments have similar properties to the special filaments prepared by Hibi, namely high coherence and high brightness, but are more robust and easier to make.  
A.E.I. Research Laboratory
- 7895 SAMPLING OF SUB-MICRON PARTICLES FOR ELECTRON MICROSCOPY.**  
C.E. Billings, W.J. Megaw and R.D. Wiffen.  
Nature (GB), Vol. 189, 336 (Jan. 28, 1961).  
Cartwright (Abstr. 1282 of 1955) observed by optical microscopy that deposition of dust particles in a thermal precipitator occurred preferentially over the grid bars if the collecting film was supported on a copper grid. To test that this experimental error also occurs for Aitken nuclei in the size range 0.01-0.1  $\mu$ , a technique was devised for marking them with atoms of thorium B and then observing the distribution in the deposit by autoradiography. Preferential deposition is found over the grid bars of a copper grid covered with an evaporated carbon film. The use of carbon-coated coverslips avoids this difficulty.  
V.E. Cosslett
- 7896 VICTAWET AND SODIUM METAPHOSPHATE AS PARTING AGENTS FOR ELECTRON MICROSCOPE REPLICAS.** J.O. Stiegler and T.S. Noggle.  
Rev. sci. Instrum. (USA), Vol. 32, No. 4, 406-8 (April, 1961).  
Victawet is a nonfoaming anionic wetting agent composed of Na<sub>2</sub>R<sub>5</sub>(P<sub>3</sub>O<sub>10</sub>)<sub>2</sub>, where R = 2-ethylhexyl. The authors show that the active material obtained in the use of Victawet as a parting layer for electron microscope replicas is the inorganic decomposition product sodium metaphosphate (SMP). The results of an investigation of the parting layer characteristics of SMP suggest its use in applications which have previously employed Victawet. Measurements with radioactive tracers indicate that on smooth surfaces reproducible stripping can be realized with parting layers of SMP a few molecular dimensions in thickness. The use of a ribbon filament source with this material is recommended to minimize shadowing effects and thus reduce the thickness of SMP required for successful stripping.
- 7897 PREPARATION OF THIN METAL FOILS FROM ORDINARY TENSILE SPECIMENS FOR USE IN TRANSMISSION ELECTRON MICROSCOPY.** P.R. Strutt.  
Rev. sci. Instrum. (USA), Vol. 32, No. 4, 411-13 (April, 1961).  
Methods are described to produce thin foils, suitable for transmission electron microscopy, from ordinary tensile specimens. The specimens were cylindrical single crystals of  $\alpha$ -brass of diameter  $\frac{1}{4}$  in. and gauge length  $\frac{1}{2}$  in. All the procedures are electrolytic in order to avoid introduction of mechanical strains.

## PHYSICAL CHEMISTRY

## THERMOCHEMISTRY . REACTIONS

7898 **LiOH HYDRATION EFFECTS IN PRESSED ALKALI HALIDE PELLETS.** R.A.Buchanan and W.A.Bowen, Jr. *J. chem. Phys. (USA)*, Vol. 34, No. 1, 348-9 (Jan., 1961).  
Water vapour can diffuse in and out freely. Bands near  $3500\text{ cm}^{-1}$  come and go respectively when a pellet is left in a humid atmosphere or is heated. The effect is more pronounced with RbBr than with KBr. G.F.Lothian

7899 **CALCULATION OF COMPLEX EQUILIBRIUM WITH AN UNKNOWN NUMBER OF PHASES.** R.H.Boll. *J. chem. Phys. (USA)*, Vol. 34, No. 4, 1108-10 (April, 1961).  
An extension of Brinkley's (Abstr. 435 of 1947) generalized procedure is proposed for calculating the equilibrium compositions for complex systems in which several phases are possible but their actual number and identities at equilibrium are not known a priori. In contrast to other methods, the present method eliminates the trial and error associated with presence or absence of phases. Thus, little computational effort is required beyond that expended when the number and identities of all phases are known. The essential equations are given together with a description of the computational procedure.

7900 **TEMPERATURE DEPENDENCE OF THE ISOTOPIC FRACTIONATION OF NITROGEN IN THE NO-NO<sub>3</sub><sup>-</sup> SYSTEM.** M.J.Stern, L.N.Kauder and W.Spindel. *J. chem. Phys. (USA)*, Vol. 34, No. 1, 333-4 (Jan., 1961).  
Measurements are described of the fractionation factors (at several temperatures) in the systems NO(gas)-0.98 M HNO<sub>3</sub> and NO(gas)-4.5 M Cu(NO<sub>3</sub>)<sub>2</sub>. Exchange in the latter is considerably slower than in the former, but has the advantage of being less involved because of the negligible solubility of NO in the salt solution. The separation factors (1.053 and 1.045) for ~1 M HNO<sub>3</sub> at 55° and 70° respectively are considerably higher than those previously reported. The equilibrium constants of the reaction  $\text{N}^{15}\text{O} + \text{N}^{14}\text{O}_3 \rightleftharpoons \text{N}^{14}\text{O} + \text{N}^{15}\text{O}_3$  at the several temperatures (in the range 25-70°) are evaluated. They are in reasonable agreement with those calculated from spectroscopic data. W.Good

7901 **OXYGEN ISOTOPE FRACTIONATION BETWEEN CALCIUM CARBONATE AND WATER.** R.N.Clayton. *J. chem. Phys. (USA)*, Vol. 34, No. 3, 724-6 (March, 1961).  
A technique is described for the total extraction of oxygen from calcium carbonate for isotopic analysis. This permits recalculation of previously published data to yield absolute values of equilibrium constants for the oxygen isotope exchange reaction between calcite and water. The equilibrium constant varies with temperature according to the empirical relationship  $\ln K = 2730\text{ T}^{-2} - 0.00256$  over the temperature range 273° - 1023°K.

**GREASELESS VACUUM VALVE USEFUL IN KINETIC STUDIES.** See Abstr. 6915

**REINTERPRETATION OF THE REACTION KINETICS OF NICKEL FERRITE.** R.C.Turnbull. *J. appl. Phys. (USA)*, Suppl. to Vol. 32, No. 3, 380S-381S (March, 1961).

The kinetics of formation of nickel from the oxide components has been studied using saturation magnetization to follow the course of the reaction. The data has been interpreted in terms of an empirical expression developed by Tamman. This expression, which gives quite satisfactory agreement with the data, is  $C = A \log t + B$ , where C is the percent of reaction product, t is the time, and A and B are constants. The sharp breaks that occur in the percent reaction versus log time curves indicate that three separate and distinct mechanisms occur. These are interpreted as (1) an initial surface diffusion of significance at temperatures in the 600° to 800°C range, (2) bulk diffusion in the temperature range from 700° to 950°C, and (3) crystallization into a relatively defect-free crystal lattice above temperatures of 950°C. Activation energies for the surface diffusion and bulk diffusion are 30 and 18 kcal, respectively. Both the low activation energy for the bulk diffusion in comparison to the surface diffusion, and the high initial reaction rate at higher temperatures, suggest that the reaction proceeds through iron diffusing into an active metastable NiO phase.

**REACTION OF CYCLOPROPANE WITH IODINE AND SOME OBSERVATIONS ON THE ISOMERIZATION OF CYCLOPROPANE.** S.W.Benson.

*J. chem. Phys. (USA)*, Vol. 34, No. 2, 521-6 (Feb., 1961).  
The kinetic and thermodynamic data of Ogg and Priest on the system  $\text{I}_2 + \text{cyclopropane} \rightleftharpoons \text{ICH}_2\text{CH}_2\text{CH}_2\text{I}$  are re-examined. Using an entropy for  $\text{ICH}_2\text{CH}_2\text{CH}_2\text{I}$ , estimated from additivity rules of  $93.0 \pm 1.5$  e.u. and the experimental value of  $K_{\text{eq}}$ ,  $\Delta H^\circ$  is found to be  $-19.4 \pm 0.9$  kcal. This gives  $H_f^\circ(\text{ICH}_2\text{CH}_2\text{CH}_2\text{I}) = 8.2$  kcal/mole and the use of group additivity rules allow the values of  $\Delta H_f^\circ$  for EtI and  $n\text{-C}_3\text{H}_7\text{I}$  to be fixed at  $-3.3 \pm 0.5$  and  $-8.3 \pm 0.5$  kcal/mole, respectively. For  $\text{CH}_3\text{I}$ ,  $\Delta H_f^\circ = 1.6 \pm 1$  kcal/mole. The kinetic mechanism is also re-examined and from entropy and energy estimates for the free radical species, values of all of the rate constants are evaluated. These are in good agreement with values for similar reactions. It is proposed that the  $\text{I}_2$ -catalyzed isomerization of cyclopropane proceeds through the step  $\text{I} + \text{ICH}_2\text{CH}_2\text{CH}_2\text{I} \rightarrow \text{HI} + \text{ICH}_2\text{-CH=CH}_2 + \text{I}$ , followed by a rapid, atom-catalyzed reaction of allyl iodide with HI to give propylene. The rate constants for such a step are also in good agreement with those for similar reactions. Extension of the data to cyclopropane-propylene isomerization is made and it is shown that the most reasonable path involves the trimethylene radical as an intermediate. Its lifetime is, however, very short  $\sim 10^{-11}$  sec. Slater's model for this reaction is shown to be implausible. These data indicate an activation energy for the cyclization of the trimethylene free radical of about 8 kcal. This is reasonable only if the end  $\text{CH}_2$  groups in trimethylene are interacting via a "bent" bond. In such case the activation energy arises from the necessity for eclipsed configurations. A similar analysis is made for cyclobutane and the tetramethylene radical with compatible results. For cyclopropane the strain energy is 30 kcal and for cyclobutane 28 kcal.

**DECOMPOSITION RATE OF NITRIC OXIDE BETWEEN 3000 AND 4300°K.** E.Freedman and J.W.Daiber. *J. chem. Phys. (USA)*, Vol. 34, No. 4, 1271-8 (April, 1961).

Time-resolved absorption spectra of shock-heated nitric oxide in the far ultraviolet were taken using photoelectric detection. The decomposition rate of nitric oxide between 3000 and 4300°K was thereby measured. The initial rate was found to be the sum of the direct dissociation reaction,  $\text{NO} + \text{Ar} \rightarrow \text{N} + \text{O} + \text{Ar}$ , with  $k = 7 \times 10^{12} \exp(-150000/\text{RT})$  litres/mole sec, and the bimolecular reaction,  $2\text{NO} \rightarrow \text{N}_2 + \text{O}_2$ , with  $k = 4.8 \times 10^{20} \text{T}^{-5/2} \exp(-85500/\text{RT})$  litres/mole sec.

**REACTION OF NITROGEN ATOMS WITH OZONE.** Mei Chio Chen and H.A.Taylor.

*J. chem. Phys. (USA)*, Vol. 34, No. 4, 1344-7 (April, 1961).  
The reaction of ozonized oxygen and active nitrogen at room temperature was shown to produce, almost exclusively, nitrous oxide. Rate measurements in a flow system have been analyzed as involving a primary reaction  $\text{N} + \text{O}_3 \rightarrow \text{NO} + \text{O}_2$ . Accepting present values for the specific rates of subsequent reactions of nitric oxide, the rate of the primary reaction is found to be  $10^{10}$  ml/mole sec. This is several orders faster than the reaction of nitrogen atoms and oxygen molecules and many orders faster than the three-body recombination of atomic nitrogen and atomic oxygen, substantiating the Barth-Kaplan suggestion of the probable source of nitric oxide in the upper atmosphere.

**SOME ASPECTS OF THE SELF-HEATING AND IGNITION OF SOLID CELLULOSIC MATERIALS.**

P.H.Thomas and P.C.Bowes. *Brit. J. appl. Phys.*, Vol. 12, No. 5, 222-9 (May, 1961).

The self-heating and self-ignition of fibre insulating board and similar materials are discussed in the light of the well-known theory of thermal explosion. It is pointed out that the simple theory for a single reaction neglecting reactant loss during the induction period is inadequate for the interpretation of all the data published by Mitchell [Quarterly of the National Fire Protection Association (USA), Vol. 45, No. 165 (1951)]. In the case of wood fibre insulating board it is suggested that the reaction leading to significant increases in temperature at relatively low ambient temperatures is not that responsible for ignition; ignition appears to be mainly the result of other reactions which become appreciable only at higher temperatures. Some experimental results in

support of this contention are given, and it is estimated that the total heat of reaction is  $80 \text{ cal g}^{-1}$ . The induction times reported by Mitchell for three materials show one of them (cotton linters) to be different in its behaviour from the other two.

**A PLASTIC CAPSULE TECHNIQUE FOR THE COMBUSTION CALORIMETRY OF VOLATILE OR CHEMICALLY REACTIVE COMPOUNDS: THE HEAT OF COMBUSTION OF POLYTHENE.**  
See Abstr. 6986

#### STABILITY OF LAMINAR FLAMES.

7907 R.E. Petersen and H.W. Emmons.

Phys. of Fluids (USA), Vol. 4, No. 4, 456-64 (April, 1961).

Markstein theory of stability of laminar flames is shown to be supported by experimental results on oscillated laminar propane-air flames. Disturbances in appropriate wavelength ranges grow and distort while for other ranges disturbances are damped. These facts imply important restrictions on the nature of a turbulent flame and its interaction with the surrounding flow field.

#### DISCONTINUITY PROPERTIES OF LAMINAR FLAMES.

See Abstr. 6977

#### TURBULENCE STRUCTURE OF GASEOUS DETONATION.

7908 D.R. White.

Phys. of Fluids (USA), Vol. 4, No. 4, 465-80 (April, 1961).

Self-sustaining and overdriven detonations in  $2\text{H}_2 + \text{O}_2 + 2\text{CO}$  were studied in a shock tube at initial pressures from 0.01 to 1.4 atm. Measurements have included pressure, density obtained interferometrically, and luminosity whose intensity is shown to be proportional to  $[\text{CO}][\text{O}]$ . Strongly overdriven waves are one dimensional and are followed by the calculated equilibrium state. Self-sustaining detonations are followed by a state in which the pressure and density are lower than calculated according to the usual Chapman-Jouguet hypothesis, and in which the flow is supersonic with respect to the wave front. Furthermore, the flow in and behind the reaction zone invariably appears to be turbulent. In an examination of the implications of this turbulence, a C-J detonation is considered to be one with the minimum velocity of propagation which will satisfy the conservation relations for turbulent flow at the rear of reaction zone. It is shown that this minimum (C-J) velocity is slightly greater than that calculated assuming turbulence is not present, and that the final state attained following the decay of turbulence can lie either on the "strong" or "weak" detonation branch of the Hugoniot curve. Intermediate states, including the conventionally calculated C-J state, in general do not represent stable solutions. The self-sustaining detonation, which must correspond to the weak detonation solution, appears as a special case of a C-J detonation.

#### TWO-REACTION STEADY DETONATIONS.

7909 J.J. Erpenbeck.

Phys. of Fluids (USA), Vol. 4, No. 4, 481-92 (April, 1961).

Steady, one-dimensional detonations in an idealized, three-component, gaseous medium with reactions  $\text{A} = \text{B}$ ,  $\text{A} = \text{C}$ , proceeding with Arrhenius unimolecular kinetics are investigated by way of exemplifying the Wood-Salsburg analysis as well as delineating the behaviour at the troublesome "pathological" locus for this special case. The analysis is detailed for the exothermic parallel-reaction case with large disparity in the heats of reaction, but results for other cases are mentioned. Stability conditions for a pathological detonation are reformulated as conditions on the parameters of the system which, though necessary, are by no means sufficient. For both the exothermic parallel-reaction case and the consecutive-reaction case, with the second reaction endothermic, it appears that the stability conditions are not inconsistent with the existence of a pathological solution. Numerical results for several systems at the equilibrium Chapman-Jouguet detonation velocity are presented, including one in which the equilibrium CJ condition is inapplicable.

#### SHOCK INITIATION OF DETONATION IN LIQUID EXPLOSIVES.

7910

A.W. Campbell, W.C. Davis and J.R. Travis.

Phys. of Fluids (USA), Vol. 4, No. 4, 498-510 (April, 1961).

Experimental studies of the initiation of liquid explosives by strong plane shocks (pressures 50 to 100 kb) are described. These experiments demonstrate thermal explosion as a result of shock heating in the explosive. When the shock enters the explosive, the explosive is heated. After a delay, detonation in the heated, compressed explosive begins at the interface, where the explosive has been hot longest. The detonation proceeds through the compressed explosive at a velocity greater than the steady-state velocity in uncompressed explosive, overtaking the initial shock and overdriving

detonation in the unshocked explosive. Most of the work has been done on nitromethane, but molten TNT, mclten DINA, Dithelite 13, and single crystals of PETN are shown to behave in the same way. Experiments showing the effects of bubbles and shock interactions in the explosive are presented.

#### SHOCK INITIATION OF SOLID EXPLOSIVES.

7911 A.W. Campbell, W.C. Davies, J.B. Ramsay and J.R. Travis.

Phys. of Fluids (USA), Vol. 4, No. 4, 511-21 (April, 1961).

Initiation phenomena in solid explosives produced by strong shock waves are described. Shock pressures in the explosive were between 20 and 200 kb. It is demonstrated that in the usual case the shock wave travels not as an inert shock, but as a shock to which the explosive contributes energy, probably from reaction at voids and defects. This slightly reacting shock travels at increasing velocity for some distance, typically 1 cm in the experiments described, and then in a travel of perhaps 0.01 cm becomes full detonation, moving at full velocity. The increase to full detonation velocity occurs without overshoot. Experiments demonstrating the variation of sensitivity to shock with density, grain size, and other properties are discussed. The explosives studied were cyclotol B, TNT, plastic-bonded HMX, and nitromethane-carborundum mixtures.

#### PRESSURE DEPENDENCE OF THE ABSOLUTE

7912 CATALYTIC EFFICIENCY OF SURFACES FOR REMOVAL OF ATOMIC NITROGEN. R.A. Young.

J. chem. Phys. (USA), Vol. 34, No. 4, 1292-4 (April, 1961).

By utilizing the nitrogen afterglow to monitor the exponentially decaying nitrogen atom concentration within a closed observation bulb, the low catalytic efficiency of four wall coatings is measured over a large pressure range. The catalytic efficiency of all surfaces is essentially independent of pressure.

#### MEASUREMENTS OF THE DIFFUSION COEFFICIENT

7913 OF ATOMIC NITROGEN IN MOLECULAR NITROGEN AND THE CATALYTIC EFFICIENCY OF SILVER AND COPPER OXIDE SURFACES. R.A. Young.

J. chem. Phys. (USA), Vol. 34, No. 4, 1295-301 (April, 1961).

By utilizing the first positive bands of nitrogen to monitor the decay of atomic nitrogen caused by diffusion to a catalytic surface, the diffusion coefficient of atomic nitrogen in molecular nitrogen was investigated, leading to a probable value of  $290/p \text{ cm}^2 \text{ sec}^{-1}$ . The catalytic efficiency  $\gamma$  of silver and copper oxide surfaces is found to be of the general form  $\gamma = a/(bp + c)$ , where  $p$  is the molecular nitrogen pressure,  $b$  and  $c$  are constants for each surface, and  $a$  is a constant independent of the surface.

#### APPARATUS FOR METHANE SYNTHESIS FOR

7914 RADIOCARBON DATING.

A.W. Fairhall, W.R. Schell and Y. Takashima.

Rev. sci. Instrum. (USA), Vol. 32, No. 3, 323-5 (March, 1961).

A simple apparatus is described whereby any quantity of  $\text{CO}_2$  up to several moles can be converted to methane in one step by catalytic hydrogenation using a ruthenium catalyst. The conversion is very rapid, the entire operation being carried out in about 3 hours. The over-all yield is greater than 98%, and the methane is of high purity.

## ELECTROCHEMISTRY

7915 CONTRIBUTION TO THE STUDY OF ELECTRODE POTENTIALS OF SEMICONDUCTORS IN SOLUTION.

G. Feuillade.

C.R. Acad. Sci. (France), Vol. 252, No. 9, 1288-90 (Feb. 27, 1961).

Expressions for this potential are obtained for a semiconductor electrode in the presence and in the absence of light.

P.T. Landsberg

ANODIC DISSOLUTION OF GERMANIUM CONTAINING A P-N JUNCTION. See Abstr. 7657

ELECTROLYTIC CUTTING OF THIN METAL FOILS FROM ORDINARY TENSILE SPECIMENS. See Abstr. 7897

PHOTOCHEMISTRY OF THE  $V_1$  CENTRE. See Abstr. 7602

## PHOTOCHEMISTRY RADIATION CHEMISTRY

- 7916 ELIMINATION OF MOLECULAR HYDROGEN FROM  
ALKYL FREE RADICALS. A.S.Gordon and S.R.Smith.  
J. chem. Phys. (USA), Vol. 34, No. 1, 331-2 (Jan., 1961).

Simultaneous photolysis and pyrolysis of  $C_2H_6$ -acetone- $d_6$  mixtures shows that an H-atom mechanism does not account for the observed  $H_2/HD$  ratios. Molecular hydrogen is eliminated and this has been shown to be so for all cyclo-alkyl radicals from  $C_4$  to  $C_7$  as well as for propyl and butyl radicals. Results indicate that the pre-exponential factor for the molecular hydrogen elimination reaction is considerably smaller than for the corresponding cleavage of the C-C bond.  
R.C.Seymour

- 7917 PHOTODECOMPOSITION OF BIACETYL VAPOR.  
J.Heicklen and G.B.Porter.

J. chem. Phys. (USA), Vol. 34, No. 2, 686 (Feb., 1961).  
Six reasons are given for rejecting Dubois' conclusions (Abstr. 14129 of 1960) that the data of Sheats and Noyes [J. Amer. Chem. Soc., Vol. 77, 1421, 4532 (1955)] can be explained by a wavelength and temperature-dependent decomposition of the initially formed excited molecule instead of by two distinct decompositions, one wavelength dependent and the other temperature dependent.  
W.Good

- 7918 MASS SPECTROMETRIC TEST FOR AN INTERMEDIATE  
IN A PHOTOCHEMICAL REACTION INVOLVING  
CHLORINE. G.A.Ropp, C.E.Melton and P.S.Rudolph.  
J. chem. Phys. (USA), Vol. 34, No. 2, 688-9 (Feb., 1961).

No mass spectrometric peaks corresponding to chloroformic acid were found in the photochemical reaction of formic acid with chlorine. The applicability of the technique used for the detection of intermediates in other photochemical reactions is discussed.  
W.Good

- 7919 TRANSIENT MEASUREMENTS OF PHOTOCHEMICAL  
PROCESSES IN DYES. I. THE PHOTOSENSITIZED  
OXIDATION OF PHENOL BY EOSIN AND RELATED DYES.  
L.I.Grossweiner and E.F.Zwicker.

J. chem. Phys. (USA), Vol. 34, No. 4, 1411-17 (April, 1961).  
Irradiation of the fluorescein dyes in their visible absorption bands excites metastable triplet states which decay by the bimolecular reaction of triplet molecules. A rapid reaction of phenol with triplet eosin is shown by the retardation of the rate of aerobic photobleaching and an acceleration of the rate of triplet disappearance. The primary photochemical reaction between phenol or phenolate ion with the triplet dye produces a phenoxy free radical and a reduced dye free radical, which disappear in second-order processes. Numerical values are given for the rate constants of several elementary reactions. The competition between physical quenching and charge-transfer chemical reaction can be explained by spin-conserving processes.

- 7920 ENERGY TRANSFER IN POLYETHYLENE AND POLY-  
ETHYLENE-POLYBUTADIENE MIXTURES DURING  
GAMMA IRRADIATION. M.Dole and T.F.Williams.  
Disc. Faraday Soc. (GB), No. 27, 74-82 (1959).

"Energy transfer" Discussion, Nottingham, 1959 (see Abstr. 4920 of 1961).

## DISPERSIONS . COLLOIDS

- 7921 DEVELOPMENT AND PRELIMINARY TESTING OF A  
DEVICE FOR ELECTROSTATIC CLASSIFICATION OF  
SUBMICRON AIRBORNE PARTICLES. G.Langer and J.L.Radnik.  
J. appl. Phys. (USA), Vol. 32, No. 5, 955-7 (May, 1961).

A practical apparatus was developed for electrostatic size classification of aerosol particles of 0.1 to a few microns in diameter. The aerosol, surrounding by a sheath of clean air, is charged by passing it closely over an intense positive discharge at high speed. It enters as a fine filament at 1 m/sec into an electrostatic field between parallel plates. Charging rates several times above those predicted by conventional theory permitted good resolution. A high natural charge on the aerosols had an adverse effect on classification. Various aerosols were examined, and results of practical significance were obtained. With salt aerosols, strong higher-order Tyndall spectra were observed from the classified deposit.

- 7922 THE EFFECT OF ADSORPTION ON THE VAN DER  
WAALS INTERACTION OF SPHERICAL COLLOIDAL  
PARTICLES. M.J.Vold.

J. colloid Sci. (USA), Vol. 16, No. 1, 1-12 (Feb., 1961).  
A general formula is derived for the interaction of spherical particles surrounded by any number of concentric shells of adsorbed material. The net interaction energy seems to be invariably negative (attraction) regardless of the magnitude of the van der Waals' constants of the materials comprising the particle, medium, and adsorbed substances. This result is demonstrated for one and for two adsorbed layers (i.e. a single layer of oriented amphipathic molecules), although it was not found feasible to develop a general proof. The interaction energy of solvated particles may be reduced by factors of the order of 5 to 50 compared with that of unsolvated particles. However, if current estimates of the magnitude of the van der Waals' constants are correct, flocculation can be inhibited by solvation alone only for small particles (< about 500 Å radius) and quite thick layers (> about 20 Å). Stabilization is most effective when the van der Waals' constant for the adsorbed material is either greater or less than the van der Waals' constants for both particle and medium.

## PHYSICAL METHODS OF CHEMICAL ANALYSIS

- 7923 SMALL VOLUME LONG PATH INFRARED CELLS  
FOR LIQUIDS. D.S.Erley, B.H.Blake and W.J.Potts.  
Appl. Spectrosc. (USA), Vol. 14, No. 4, 108-9 (1960).

An infrared cell is described for use in the determination of trace organic compounds in blood where the possibility of fractionation before analysis must be obviated.  
G.I.W.Llewelyn

- 7924 AN OMEGATRON FOR THE QUANTITATIVE ANALYSIS  
OF GASES. A.Klopper and W.Schmidt.  
Philips tech. Rev. (Netherlands), Vol. 22, No. 6, 195-203 (1960-61).

A pair of side plates were added to the original instrument. When a suitable potential is applied to these plates, the ion current can be brought to an optimum value at any mass which is in resonance. For a magnetic induction B of 0.5 Wb/m<sup>2</sup> and an r.f. voltage of 1 V<sub>rms</sub>, the maximum permissible pressure is 10<sup>-8</sup> mm Hg. The lowest measurable pressure of any one kind of gas is  $p_{min} \approx 1 \times 10^{-12}$  mm Hg, when a d.c. amplifier is available capable of detecting a current of 10<sup>-16</sup> A. The resolution is such that masses 30 and 31 can be distinguished. The accuracy of measurement is 10%.

# GEOPHYSICS

## 7925 SOME ASPECTS OF ELASTIC WAVE PROPAGATION IN FLUID-SATURATED POROUS SOLIDS.

J. Geertsma and D.C. Smit.

Geophysics (USA), Vol. 26, No. 2, 169-81 (April, 1961).

Biot's equations for the propagation of dilational waves in fluid-saturated porous solids in the low-frequency range are analysed for the purpose of application in geophysical research. The deformation constants of the system are unravelled in terms of compressibilities and porosity, and suitable approximate solutions for wave velocity and attenuation of the waves of both the first and second kind are obtained. A saturated elastic porous solid is found to behave, as far as the wave of the first kind is concerned, approximately as a standard element. The wave of the second kind rapidly dies out with increasing distance from the source and consequently one might infer that in seismic studies only the wave of the first kind needs consideration. It is shown, however, that its presence has an effect upon the reflection and absorption at any interface between two different fluid-saturated porous solids. At such an interface a wave of the second kind is again generated. General formulae for the reflection and absorption for normal incidence at the interface are obtained, which include the effect of second-wave generation. Additional results of the investigation are the following: a rather simple formula for the speed of sound in sedimentary rocks (the wave of the first kind) is obtained, which has to replace the so-called "time-average relation" now sometimes used. A comparison between the results obtained, and published results on wave propagation in simpler fluid-solid systems, such as, for instance, suspensions, showed some weak points in the older theories. Suggestions for possible improvements are given.

## 7926 ESTIMATION OF URANIUM AND THORIUM IN RADIOACTIVE ORES BY $\gamma$ -SPECTROMETRY.

L. Avan and P. Keller.

C.R. Acad. Sci. (France), Vol. 252, No. 8, 1135-7 (Feb. 20, 1961). In French.

The arrangement consists of two single-channel selectors and a pulse amplitude discriminator, the detector being a well-type NaI : Tl crystal coupled to a photomultiplier. The resolution was 8.5% for the  $\text{Cs}^{137}$  661 keV  $\gamma$ -rays. The effect of  $\beta$ -radiation is eliminated by the use of an absorber (equivalent thickness 1.12 g/cm<sup>2</sup>) and the method, which can be employed whatever the degree of radioactive equilibrium, can also study the effect of self-absorption of the  $\gamma$ -radiation. Results are tabulated for the equilibrium and the non-equilibrium case, and graphs show spectra of the uranium and of the thorium family and of both families in radioactive equilibrium. I.C. Demetsopoulos

EFFECT OF AN INTERNAL WAVE ON SOUND IN THE OCEAN. See Abstr. 6932

# ATMOSPHERE

(Troposphere and Stratosphere)

## 7927 ARCTIC ATMOSPHERIC STRUCTURE TO 250 km. H.E. Lagow, R. Horowitz and J. Ainsworth.

Planet. Space Sci. (GB), Vol. 2, No. 1, 33-8 (Oct., 1959).

Atmospheric density, pressure and scale height data were obtained with Aerobee-Hi rockets fired at Fort Churchill as part of the IGY programme. Four were fired at Fort Churchill, 59°N; a fifth at White Sands, 33°N. The analysis of the data from the first two rockets is nearly complete. The results show: (i) the summer densities from 30 to 70 km at 59°N are approximately 5 - 10% higher than the Rocket Panel values for 33°N, (ii) the winter densities from 25 to 40 km are 10 - 20% lower than corresponding summer values at 59°N; thus they are 5 - 10% lower than the 33°N Rocket Panel values, (iii) the daytime atmospheric density at 200 km at 59°N is higher both in the summer and in the winter than the summer value of  $1.4 \pm 0.5 \times 10^{-7}$  g/m<sup>3</sup> for 33°N obtained in August 1951. At 59°N and 200 km altitude the summer value is  $6.7 \pm 2 \times 10^{-7}$  g/m<sup>3</sup> while the corresponding winter value is

$3.6 \pm 1.0 \times 10^{-7}$  g/m<sup>3</sup> and (iv) the summer atmospheric pressure at 110 km at 59°N is  $(6.5 \pm 0.8) \times 10^{-5}$  mm Hg and is a factor of 2.5 higher than the corresponding 33°N value. A tentative result from the third flight was obtained. This winter night flight gives a density value of  $1.3 \pm 0.6 \times 10^{-7}$  g/m<sup>3</sup> at 202 km above 59°N. This value is a factor of 3 lower than was obtained at the same latitude on a winter day and is equal to the value obtained on a summer day at 33°N.

ATMOSPHERIC DENSITIES AT ALTITUDES UP TO 750 km OBTAINED FROM THE VANGUARD ORBIT DETERMINATION PROGRAMME. See Abstr. 6750

ATMOSPHERIC DENSITY MEASUREMENTS BETWEEN 30 AND 60 km USING A MODULATED SEARCHLIGHT BEAM. See Abstr. 6956

## 7928 ATMOSPHERIC WAVES CAUSED BY LARGE EXPLOSIONS. J.N. Hunt, R. Palmer and W. Penney.

Phil. Trans A (GB), Vol. 252, 275-315 (Feb. 18, 1960).

Considers the harmonic oscillations of several simple model atmospheres. The oscillations are of two types. In the first, the kinetic energy per unit volume tends to zero at great heights; in the second, the kinetic energy per unit volume remains finite. A large explosion at ground level excites a spectrum of both types of oscillation. The pulse ultimately separates into two parts — a train of travelling waves which can be observed at ground level at great distances, and a train of travelling wave which disappears into the upper atmosphere. The complete range of experimental observations on the pressure oscillations caused by explosions of energies varying between  $10^{20}$  and  $10^{24}$  ergs can only be interpreted with model atmospheres having one or more sound channels, i.e. having at least one minimum in the temperature-height relationship of the atmosphere. In spite of the complexity of the phenomena, the theory throws light on some of the characteristic features of the observations. The average period of the largest waves is roughly proportional to the cube root of the energy released by the explosion. The amplitudes of the waves from large explosions can be calculated. Conversely, good records enable the size of the explosion to be estimated. The energy of the Siberian meteorite of 1908 was about  $10^{16}$  cal, or 10 MT (T signifying a ton of t.n.t.).

## 7929 MIRAGES. J.H. Gordon.

Smithsonian Rep. (USA), 1959, 327-46. Review.

## 7930 DEFINITION AND MEASUREMENT OF THE MEAN FIELD OF ATMOSPHERICS OF IMPULSIVE TYPE.

F. Carbenay.

C.R. Acad. Sci. (France), Vol. 251, No. 17, 1756-8 (Oct. 24, 1960). In French.

Considering that atmospheric generally exhibit a pulse character, an expression is derived for the mean effect on a receiver, having suitable amplification and linear detection, in terms of the equivalent effect of an electromagnetic field having the frequency to which the receiver is tuned. G.M. Brown

## 7931 ELECTROMAGNETIC RADIATION FROM LIGHTNING STROKES. E.L. Hill.

J. Franklin Inst. (USA), Vol. 263, No. 2, 107-20 (Feb., 1957).

A theory is given of the spectral distribution and the absolute amount of low frequency electromagnetic radiation emitted from a vertical lightning stroke from cloud to ground. The calculation depends on an assumed physical mechanism for the flow of charge on the discharge channel, but the model corresponds closely to the empirical observations of Schonland, Pierce, and others. The radiated energy has a maximum intensity at about 11 kc/s and a total width at half-maximum of 12 kc/s. The predicted radiation in the megacycle region agrees reasonably well with that reported by Chandrasekhar Aiyar [Abstr. 5371 B (1955); Proc. Inst. Radio Engrs (USA), Vol. 43, 966-74 (1955)], although the present theory was developed primarily for the low frequency region. The total energy radiated in one leader and return stroke is estimated to be about 220 000 joules.

EXCITATION OF VLF AND ELF RADIO WAVES BY A HORIZONTAL MAGNETIC DIPOLE. See Abstr. 7142

- 7932 LATITUDINAL EFFECT IN THE TRANSFER OF RADIOCARBON FROM STRATOSPHERE TO TROPOSPHERE. H. Tauber.  
Science (USA), Vol. 133, 461-2 (Feb. 17, 1961).

Latitudinal variations in the descent of bomb-produced radio-carbon from the stratosphere is suggested by differences in tropospheric  $C^{14}$  activity. The magnitude of a similar latitudinal effect in the pre-bomb steady state is estimated. This effect may be part of the explanation of the short-term oscillations in  $C^{14}$  activity found in tree-rings from the last 1300 years.

- 7933 FALLOUT FROM NUCLEAR DETONATIONS OF FEBRUARY AND APRIL 1960.  
P.K. Kuroda, H.L. Hodges and H.E. Moore.  
Science (USA), Vol. 133, 1030-1 (April 14, 1961).

A sharp increase in the ratio of strontium-89 to strontium-90 in rain was observed at Fayetteville, Arkansas, after the French nuclear detonations of February and April 1960. Experimental data obtained suggest the possibility that part of the debris from atom bombs detonated in the tropical region may enter the stratosphere.

## UPPER ATMOSPHERE IONOSPHERE

(See also Space Research. Abstracts on radiowave propagation in ionized media will also be found under Electromagnetic Waves)

- 7934 SKIP-DISTANCE RAY-FOCUSING IN THE IONOSPHERE.  
E. Golton.

Nature (GB), Vol. 189, 48-9 (Jan. 7, 1961).

Observations of 20 Mc/s signals from satellite Sputnik 3 received at Slough on occasions when the satellite was close to or beyond the horizon and at heights below 300 km, provide evidence for strong ionospheric focusing of waves travelling along paths close to the skip-distance path. The effect has been observed when the signal is received by direct reflection from the ionosphere, and when a ground reflection precedes the ionospheric one. G.M. Brown

EFFECT OF IONOSPHERE ON RADIO SIGNALS FROM EARTH SATELLITES. See Abstr. 6753

- 7935 A MAXIMUM OF TEMPERATURE IN THE MIDDLE IONOSPHERE. O. Burkard.  
Nature (GB), Vol. 189, 474 (Feb. 11, 1961).

From examination of the shape of electron density profiles for Puerto Rico, with the assumption of a particular formula for the electron loss coefficient, it is deduced that the atmospheric scale height is greatest at an altitude of about 200 km. H. Rishbeth

- 7936 ROCKET ELECTRON DENSITY MEASUREMENTS AT FORT CHURCHILL, CANADA.  
A.W. Adey and W.J. Heikkila.

Canad. J. Phys., Vol. 39, No. 1, 219-21 (Jan., 1961).

Comparison of N(h) profiles derived from an instrumented Aerobee-150 rocket using the two-frequency, phase-comparison method and from a true-height analysis applied to an ionogram obtained at the same time. The agreement is good when the E-region traces are very carefully scaled. G.M. Brown

- 7937 ENHANCEMENT OF IONIZATION IN THE E-LAYER DUE TO SOLAR FLARES DURING THE INTERNATIONAL GEOPHYSICAL YEAR. G.H. Bazzard.  
Nature (GB), Vol. 189, 47-8 (Jan. 7, 1961).

Comparison of the values of  $f_oE$  for Slough for the hour immediately preceding the commencement of a flare, and for the two succeeding hours, with the normal values for these hours shows that there is a significant increase following flares of class 3 and 2<sup>+</sup>. The comparatively slow rate of return to normal suggests that the ionization is controlled throughout by the intensity of the E-layer ionizing flare radiation. G.M. Brown

- 7938 LUNAR TIDE IN THE F2 LAYER OF THE IONOSPHERE NEAR THE GEOMAGNETIC EQUATOR. R.G. Rastogi.  
Nature (GB), Vol. 189, 214-15 (Jan. 21, 1961).

Analysis of the lunar variation of foF2 at Leopoldville shows that it is completely out of phase with that at any other equatorial station, but is very nearly the same as that at Ahmedabad. This suggests that similar lunar variations of foF2 occur at stations having the same magnetic latitude rather than the same geomagnetic latitude. G.M. Brown

- 7939 FURTHER STUDIES OF "SPREAD-F" AT BRISBANE. I. EXPERIMENTAL. G.G. Bowman.  
Planet. Space Sci. (GB), Vol. 2, No. 2-3, 113-49 (April, 1960).

For previous work see Abstr. 7080 of 1956. Rotating-spaced loops recorded the azimuths-of-arrival of pulsed 3.84 Mc/s signals from Armidale (202°, 355 km from Brisbane); also pulsed signals at the same frequency, from a transmitter on the site of the loops. These and other normal-incidence records indicate that the irregularities of the F2-layer responsible for "Spread-F" records at Brisbane, are ripples of considerable lateral extent with a "wavelength" varying from 20 km to over 100 km. The position of the ripple in each ionization contour changes with height in such a manner as to suggest a simple relationship with the geomagnetic field orientation. Seasonal variations of the phenomenon show a winter maximum and a summer sub-maximum, and there is a distinct inverse sunspot-cycle relationship. The type of spreading defined as range-spreading generally has a peak of occurrence around midnight, and that defined as frequency-spreading peaks during the sunset and sunrise periods, after an allowance is made for a diurnal variation associated with the changing  $f_oF2$  value.

- 7940 FURTHER STUDIES OF "SPREAD-F" AT BRISBANE. II. INTERPRETATION. G.G. Bowman.  
Planet. Space Sci. (GB), Vol. 2, No. 2-3, 150-6 (April, 1960).

The experimental results for the phenomenon, revealed from the analysis presented in Pt I of this paper, are discussed. It is deduced that "Spread-F" results from a ripple structure in the ionization contours of the F2-layer. Model ionization distributions are proposed, and ray-paths drawn, in an endeavour to explain the various aspects of the types of "Spread-F" classified in Pt I. The evidence suggests that the type of spreading observed is determined by, (i) the  $f_oF2$  variation at the time, (ii) the amplitude of the ripples, and (iii) the spacing between the ripples. If the ripple amplitude is small, no spreading will be observed. The ripples appear to be present all the time, and their amplitudes seem to become greater with an increase in F2-layer height.

- 7941 SPREAD-F AND THE LATITUDE VARIATION OF OCCURRENCE OF WHISTLERS. D.G. Singleton.  
Nature (GB), Vol. 189, 215-16 (Jan. 21, 1961).

The decrease in whistler activity which occurs for geomagnetic latitudes  $< \sim 50^\circ$  has previously been explained in terms of whistler propagation within field-aligned ducts. It is shown that this theory is consistent with the view that the lower extremities of these whistler ducts are the irregularities in the F2 layer postulated to account for the frequency-spreading component of spread-F. G.M. Brown

- 7942 EMISSION OF THE RED LINE FROM THE NIGHT SKY IN THE INTER-TROPICAL ZONE.  
D. Barbier, G. Weill, J. Daguiillon and J. Marsan.  
C.R. Acad. Sci. (France), Vol. 252, No. 2, 304-5 (Jan. 9, 1961). In French.

Routine observations made during the IGY at Tamanrassat (22° 47' N lat.) showed that the behaviour of the O I emission at 6300 Å is quite dissimilar to that found in temperate zones. In particular, the presence of sub-visual arcs following approximately a parallel of geographic latitude was established. For example, a northerly arc was observed at heights between 200 and 400 km, its location varying between 16° and 22° N lat. A similar arc was observed at a location south of the equator from an aircraft, although its features were less clearly delineated. Between the first and second halves of the night it was seen to move from 15° to 7° S lat. Throughout the inter-tropical zones, sub-visual auroral arcs were detected also in O I emission at 5577 Å. D.R. Barber

- 7943 A NEUTRAL LINE DISCHARGE THEORY OF THE AURORA POLARIS. S.I. Akasofu and S. Chapman.  
Phil. Trans A (GB), Vol. 253, 359-406 (April 27, 1961).

A theory is proposed which attempts to explain many features of the complicated morphology of auroral displays. One basis of the

theory is the presence, during magnetic disturbance, of additional or enhanced magnetic fields due to electric currents within a distance of several earth radii from the earth's centre. One such field (denoted by DCF) is due to electric currents flowing near the inner surface of the solar stream that then envelopes the earth. A hollow is carved in the stream by the geomagnetic field. The other field (denoted by DR) is that of an electric ring current, additional or enhanced, that flows westward round the earth. This is carried by the particles of the Van Allen belts. A third field (denoted by DP) is that of the disturbance currents that flow in the ionosphere, under the impulsion of electromotive forces generated mainly in polar regions. It is considered likely that during magnetic storms and auroral displays, neutral lines appear in the magnetic field near the earth. These will lie mainly on the dark side of the earth, in or near the equatorial plane, on the nearer side of the ring current. At times these lines may extend over more than  $180^\circ$  of longitude, so that a part of them may lie on the sunward side of the earth. These neutral lines are of two types,  $\sigma$  and  $\chi$ ; they appear together, in pairs. During disturbed conditions there may be more than one pair. Lines of force cross at points on  $\chi$  neutral lines, but they do not pass through  $\sigma$  neutral lines. As Dungey (Abstr. 7386 of 1953) has shown, charged particles will tend to be concentrated near  $\chi$  points (of which the  $\chi$  neutral lines are the locus). Charges drawn toward the neutral line will be discharged into the earth's atmosphere along the lines of magnetic force. We suggest that the location nature and motions of the auroral forms are determined by the position, form and motion of the  $\chi$  neutral lines, lying in or near the plane of the geomagnetic equator. It seems necessary to suppose, in addition, that an electric field arises sporadically along the  $\chi$  lines. When this is absent, the aurora appears as a quiet arc. The onset of the suggested electric field concentrates the charges move narrowly near the  $\chi$  line and near the lines of force that extend from it to the auroral zone. This produces extremely thin-rayed auroral arcs. The above concentration of electrons near an  $\chi$  neutral line produces a large flux of electrons, while the proton flux is diminished. A dynamical instability due to this flux difference (the space charge density is supposed to be very small) produces a slight separation of protons and electrons along and near the lines of force through the  $\chi$  line. Hence in the auroral ionosphere there is an associated electric field. This is usually directed towards the equator. It drives electric current, usually westward, along the auroral zones, and produces the strong magnetic disturbances (DP) there observed. Birkeland called these polar elementary storms. The rapid auroral changes are ascribed to instabilities of the magnetic field in the region near the  $\chi$  line or lines, to the rear of the earth, where the resultant magnetic field is weak. The ray structure in the auroral arc is ascribed to an instability of the thin sheet of electron flow. Cosmic rockets have shown that the magnetic field, up to and beyond ten earth radii, departs from the values corresponding to the internally produced main geomagnetic field. As yet these explorations do not seem to have disclosed the existence of reversals of the field in or near the magnetic equatorial plane. But on the basis of the auroral hypothesis, it is predicted with considerable confidence that such reversals will be found to occur, on the dark side of the earth, during great auroral displays. The theory here proposed is discussed in connection with recent I.G.Y. and I.G.C. auroral, magnetic and other data.

7944 MOTION OF GEOMAGNETIC FIELD LINES.  
C.J.Loughnan.

Nature (GB), Vol. 190, 427 (April 29, 1961).

Withdrawal of the conclusions of a previous paper (Abstr. 12137 of 1960) of the criticism of a hypothesis by Rees and Reid (Abstr. 4813 of 1960). Reference is made to a more satisfactory discussion of the hypothesis by Malville [J. geophys. Res. (USA), Vol. 65, No. 9, 3008-10 (Sept., 1960)].

7945 THE GEOMAGNETICALLY TRAPPED  
CORPUSCULAR RADIATION. J.A. Van Allen.

Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960), Vol. III, p. 7-13.

The evidence for a region containing a very high intensity of charged particles (protons and electrons) and occupying an immense region around the earth is briefly presented, with a comprehensive list of references. It is now regarded as established that the particles are trapped by the earth's magnetic field in the manner visualized by Poincare and others. It is pointed out that the determination of the absolute differential energy spectrum of each of the two components of the trapped radiation must await more elaborate experimental observations since it is a complicated function of position in space, of direction and of time.

The present observations, however, indicate that the nature of the radiation in the inner zone is quite different from that in the outer zone. The integral range-spectrum of the radiation in the inner zone falls by about two orders of magnitude from  $1\text{mg}/\text{cm}^2$  to about  $140\text{mg}/\text{cm}^2$ , then falls off more gradually toward greater stopping powers. Of the radiation which penetrates  $140\text{mg}/\text{cm}^2$ , a fraction of one per cent also penetrates several grams per square centimeter. The more penetrating component is tentatively identified as consisting of protons having energies of the order of 100 MeV. The less penetrating component is likely to be electrons having energies up to about 1 MeV. Energy fluxes as high as  $100\text{erg cm}^{-2}\text{sec}^{-1}\text{steradian}^{-1}$  have been found beneath an absorber  $1\text{mg}/\text{cm}^2$  in thickness at altitudes of 2000 km near the geomagnetic equator. It is estimated that over 95% of the energy flux is in the less penetrating, electronic component. The outer zone seems to be exclusively electronic. The energy spectrum apparently resembles that of the auroral soft radiation-rising sharply toward low energies from a practical upper limit of about 100 keV. The omni-directional flux of electrons of energy greater than 20 keV is about  $10^{11}\text{particles cm}^{-2}\text{sec}^{-1}$  in the heart of the outer zone. The origin of the trapped radiation, information of time variations, the geophysical role of the trapped radiation, and some tentative intensities are discussed. C.F.Barnaby.

7946 INVESTIGATION OF RADIATION IN OUTER SPACE.  
S.N.Vernov and A.E.Chudakov.

Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960), Vol. III, p. 19-29.

The experimental data obtained about the charged particles trapped in the earth's magnetic field (see preceding abstract) by means of Sputniks II and III and the Soviet cosmic rocket are presented. The locations of the inner and outer zones are given and the composition of particles in the zones is discussed. Constant intensity was registered by all instruments at distances exceeding 65 000 km from the earth's centre. Existing variations did not exceed  $1\%$ . The flux of charged particles was  $1800 \pm 80\text{particles m}^{-2}\text{sec}^{-1}\text{sterad}^{-1}$ , the flux of photons of energies between 45 to 450 keV was  $3200 \pm 100\text{quanta m}^{-2}\text{sec}^{-1}\text{sterad}^{-1}$ , and the flux of photons of energies between 0.45 and 4.5 MeV was  $1000 \pm 100\text{quanta m}^{-2}\text{sec}^{-1}\text{sterad}^{-1}$ . The average specific ionization of particles was 2.5 times that of the minimum. C.F.Barnaby.

7947 POSSIBLE ACCELERATION OF CHARGES BY THE  
ELECTRO-MAGNETIC FIELD OF THE MAGNETIC  
DIPOLE OF THE EARTH. Y.P.Terletsy.

Cosmic Ray Conference, Moscow, 1959, English Edition (see Abstr. 7427 of 1960), Vol. III, p. 233-8.

The discovery of the soft cosmic radiation related to the magnetic field of the Earth caused the problem of the acceleration of electrons and ions in the electromagnetic field of a rotating magnetic dipole of the Earth to be reconsidered. This paper presents the results of newly made computations of the electromagnetic field of a rotating dipole and a corrected analysis of ion motion equations in this field. General conclusions are made with regard to the nature of distribution of charges around a rotating dipole and to the analysis of possible currents. C.F.Barnaby.

## GEOMAGNETISM

7948 DESIGN OF A SECOND HARMONIC FLUX GATE  
MAGNETIC FIELD GRADIOMETER.

R.M.Morris and B.O.Pedersen.  
Rev. sci. Instrum. (USA), Vol. 32, No. 4, 444-8 (April, 1961).

An instrument for the measurement of gradients in the earth's magnetic field is described. The gradiometer, of 15 ft base length, is capable of operation for long periods with an error less than  $20\gamma$  ( $5\gamma/\text{m}$ ). Detectors are of the tuned, second harmonic flux gate type. An automatic ambient-field nulling feature was introduced to ease the requirement for exact matching of the magnetic characteristics of the gradient detectors.

7949 THE DIURNAL PROBLEM IN AEROMAGNETIC  
SURVEYING IN CANADA. K.Whitham and E.R.Niblett.  
Geophysics (USA), Vol. 26, No. 2, 211-28 (April, 1961).

Errors introduced into aeromagnetic survey results because of

geomagnetic time variations were analysed in two ways. In the first, statistical properties of average magnetic disturbance were calculated for five locations well distributed in latitude in Canada. The autocorrelation functions of vertical magnetic field fluctuations were used to estimate errors in aeromagnetic surveying as a function of the length of the base loop and the length of the traverse lines or profiles, for five latitudes. In practical applications, the r.m.s. errors are proportional to the square root of elapsed time. These results can be explained in terms of the shape of the autocorrelation functions, and models of disturbance which might produce them are discussed. In the second part, experimental results are presented of a comparison of total field intensity fluctuations measured with recording proton precession magnetometers at two pairs of stations, one pair 26 miles apart and the other 94 miles apart. The measurements were taken in Western Canada south of the auroral zone. The r.m.s. differences in the time variations have been determined quantitatively for each hour for both pairs of stations; statistically, it was found that these differences were proportional to the r.m.s. level of magnetic activity and, in this region, to the separation of the stations. The frequency distributions of the r.m.s. differences between the two pairs of stations for the month of September 1959 have been determined. A comparison of the indirect and direct methods of correction indicates that scientifically, in this region, there is little to choose between them in terms of accuracy. Operational considerations are mentioned.

7950 GEOMAGNETIC WESTWARD DRIFT AND IRREGULARITIES IN THE EARTH'S ROTATION. M.G. Rochester. Phil. Trans A (GB), Vol. 252, 531-55 (May 25, 1960).

Bullard et al's (1950) rigid-sphere model (Abstr. 9139 of 1950) for the steady westward drift of the earth's non-dipole magnetic field is extended to include the magnetic coupling provided by the presence of the higher multipole fields at the core-mantle boundary. If the first six harmonics of the observed surface field are taken into account, the retarding couple on the mantle is increased by a factor of 1.6. Using this result it would follow from Bullard's specialized model of the core that the geomagnetic dynamo mechanism generates a toroidal field of several hundred gauss in the deep interior of the core. Time-dependent perturbations of the mantle-core coupling are investigated rigorously, and it is shown that reasonable fluctuations of the fields at the core-mantle boundary are capable of explaining changes in the length of day at the rate of order 1 msec in 10 yr. The tightness of the coupling is increased by 60% over that afforded by Bullard's model. The argument provides additional evidence that the mean electrical conductivity in the bottom 2000 km of the mantle is at least  $10^{-9}$  e.m.u. A summary of knowledge of the distribution of electrical conductivity with depth in the earth is given in the Introduction.

THE CORRELATION OF SOLAR RADIO BURSTS WITH MAGNETIC ACTIVITY AND COSMIC RAYS. See Abstr. 6730

## BIOPHYSICS . PHYSIOLOGICAL PHYSICS

7951 GAMMA SPECTROGRAPH FOR THE STUDY OF THE RADIOACTIVITY OF THE HUMAN BODY.

A. Lansiart and L. Jeanmaire.

Nuclear Electronics Conference, Paris, 1958, Vol. II, (see Abstr. 12720 of 1960) p. 169-81. In French.

The subject is placed in a chamber surrounded by lead to eliminate cosmic radiation. The detector is a crystal 20 cm in diameter and 10 cm thick, coupled to a photomultiplier by a light guide. Spectrograms of normal and contaminated persons are given. W.G. Stripp

SMALL VOLUME LONG PATH INFRARED CELLS FOR LIQUIDS. See Abstr. 7923

## Hearing . Speech

7952 SOME BASIC CONSIDERATIONS IN THE ANALYSIS OF INTONATION. I. Lehiste and G.E. Peterson.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 419-25 (April, 1961).

Considers some basic problems inherent in the instrumental analysis of intonation. The problems are illustrated by a detailed analysis of one intonation contour in American English. The material studied consisted of two sets of data. The first set involved 1263 sentences recorded by one speaker with determined stress and pitch patterns. The sentences consisted of 1263 CNC words produced in an identical frame, with primary stress and the peak of the intonation contour occurring on the CNC word in the frame. The second set of frame sentences involved a subset of 70 minimally different words, uttered by five different speakers of the same general dialect. The fundamental frequency values for the various levels of the intonation contour were measured from narrow-band sound spectrograms and the measurements were correlated with the segmental phonetic structure of the sentences in which the intonation contour was produced. The intrinsic fundamental frequencies of the various syllable nuclei and the influence of preceding and following consonants are described. The relationships among successive intonation levels are discussed.

7953 TWO MULTIVARIATE STATISTICAL COMPUTER PROGRAMS AND THEIR APPLICATION TO THE VOWEL RECOGNITION PROBLEM. P.D. Welch and R.S. Wimpers.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 426-34 (April, 1961).

Describes two IBM 704 EDPM programmes which were written to aid in the development of mechanical speech recognition devices. Both are based upon multivariate statistical techniques. It further

describes the application of the two programmes to the problem of vowel recognition using fundamental frequency and formant information.

7954 ANALYSES OF SOPRANO VOICES. A. Björklund.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 575-82 (May, 1961).

An analysis of the voices of sopranos, ranging from singers without any education to artists of world fame, shows a distinct correlation between level of training and vibrato of the voice. Furthermore, analysis of the voices of singers performing in rooms with short reverberation time shows that education is important for the ability to sing correct pitch in words of more than one syllable when the syllables have different pitches. In the analysis of 66 sustained notes, some irregularities were observed in the frequency variations of the overtones. A series of recordings was carried out to detect a plausible reason for these irregularities. The results of various methods of analysis confirm the author's assertion that the sustained note from a highly trained soprano may have parts where the complex wave representing the note is not composed of harmonics.

7955 PERTURBATIONS IN VOCAL PITCH. P. Lieberman.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 597-603 (May, 1961).

An acoustic analysis of the rapid fluctuations that occur in the fundamental excitation rate, or "pitch", of normal speech was conducted with a sample of six male speakers of American English, who each read a neutral test sentence in certain "emotional" modes, i.e., as a question, an objective statement, a fearful utterance, a happy utterance, etc. A statistical analysis of the durations of approximately 7000 pitch periods was performed with an IBM 709 computer. This analysis revealed that for all possible samples consisting of three consecutive periods, the duration did not remain constant, within  $\pm 0.1$  msec, in 86% of the cases. The data also showed that the magnitude of the difference between the durations of adjacent periods was greater than 0.6 msec 20% of the time and greater than 1.0 msec 15% of the time. The magnitude of this difference increased with the duration of the periods until their duration reached 6 msec. The difference was independent of the period duration for periods longer than 6 msec. Somewhat greater differences between the durations of successive periods occurred in those samples associated with the onset and end of voicing and sudden spectral shifts. Smaller differences occurred with certain of the emotional modes that seemed to require greater conscious vocal control in their production. The output of the glottis often seemed to be like that of an oscillator with considerable overshoot. In 38% of the cases it produced a sequence

of alternately short and long duration periods. The durations of adjacent periods were not correlated. The durations of alternate long and alternate short periods, however, were highly correlated, suggesting a hysteresis effect in which the duration of each period is determined with respect to the preceding period in a quasi-random manner within a 2 msec range.

#### 7956 LIVENESS EFFECTS ON THE INTELLIGIBILITY OF NOISE-MASKED SPEECH.

P.O. Thompson, J.C. Webster and R.S. Gales.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 604-5 (May, 1961).

Liveness is a quality of sound correlated with room volume, reverberation time, and distance between the sound source and listener (or pick-up device). In this study, speech samples of varied liveness were obtained by mixing, in controlled ratios, the direct output of the talker's microphone and an output passed through a  $9 \times 7.5 \times 6$  ft reverberation chamber. In preliminary laboratory tests, the materials consisted of PB words, short phrases, and connected discourse; and varied from very low to high liveness values. The main tests were of an applied nature. Lists of sentences of low and zero (dead) liveness were transmitted over VHF radio and presented over earphones to 19 listeners in a series of intelligibility and preference tests. These lists were also presented to listeners in 105 dB SPL helicopter cabin noise. The results indicated that the live speech was less intelligible and less preferred.

#### 7957 ON THE PROPERTIES OF VOICELESS FRICATIVE CONSONANTS. J.M. Heinz and K.N. Stevens

J. Acoust. Soc. Amer., Vol. 33, No. 5, 589-96 (May, 1961).

According to an acoustical theory of speech production, the spectra of voiceless fricatives can be characterized by poles and zeros whose frequency locations are dependent on the vocal-tract configuration and on the location of the source of excitation within the vocal tract. The locations of the important poles and zeros in the spectra of fricatives can be determined by a matching process whereby comparison spectra synthesized by electric circuits are matched against the spectra under analysis. This method has been used to determine the frequencies and bandwidths of the important poles and zeros for several versions of /t/, /s/, and /ʃ/. Based on these findings, a simplified electrical model is developed for the synthesis of voiceless fricatives. The model consists of a noise-excited electric circuit characterized by a pole and a zero whose frequency locations can be varied. Stimuli generated by this model, both in isolation and in syllables, are presented to listeners for identification. The results of the listening tests are consistent with the data from the acoustic analyses and with the findings of other investigators.

#### 7958 PSYCHOPHYSICAL COMPARISON OF JUST TUNING AND EQUAL TEMPERAMENT IN SEQUENCES OF INDIVIDUAL TONES. W.D. Ward and D.W. Martin.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 586-8 (May, 1961).

Two experiments were performed to investigate one facet of the question of discriminability of melodic sequences in just intonation and equal temperament. First an ABX test was given to 20 listeners, in which prerecorded ascending diatonic scales of each type were used. Two widely different timbres were used, one flutelike and the other spectrally complex. Only three subjects gave results significantly different from chance. A second experiment employed scales deviating from equal temperament in a manner similar to the just scale, but varying in amount from -6 to -30 cents on the third, sixth, and seventh steps (mi, la, and ti). These were compared with equally tempered scales by both ABX and AX procedures. Results showed that the maximum difference between the just and equally tempered scales (16 cents) lies just below the "ABX threshold", but above the "AX threshold". It is significant that music students used here (admittedly well conditioned to equal temperament) said that when they were certain of a discrimination, it was because one of the scales contained tones which were "too flat".

#### 7959 AUDITORY MASKING AND THE CRITICAL BAND. D.D. Greenwood.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 484-502 (April, 1961).

Masked audiograms were studied as a function of the bandwidth, level, and frequency of a masking noise. In a reverse procedure, audiograms were determined when a movable, narrow, and approximately rectangular band of noise was used as signal in the presence of one or more masking tones. In both cases changes in the masked audiograms as a function of bandwidth made it possible to measure critical bandwidth. When masked audiograms were studied as a function of level discontinuous changes in their height and shape

occurred when the masking stimulus reached a certain "transition" level. If masking noises of subcritical or critical width were used, the growth of masking with level contained a discontinuity at a level of the masking stimulus equal to about 50 dB SL. An abrupt change in the shape of the masked audiograms occurred at the same level. The change of shape when a pure tone was the masking stimulus consisted in the appearance of a "notch" one critical bandwidth above the frequency of the masking tone. Findings associated with the bandwidth parameter suggest interpretations of the critical band and of masking. The changes occurring at the transition level may indicate the threshold of the inner haircells.

#### 7960 LOUDNESS SUMMATION UNDER MASKING. B. Scharf.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 503-11 (April, 1961).

The loudness of four-tone complexes centred at 250, 2000, and 4000 c/s was measured as a function of the over-all spacing,  $\Delta F$ , of the components, both in the quiet and against various levels of a uniform masking noise. When the masking noise was held at a constant level, the loudness of the complex increased more with  $\Delta F$  at moderate sensation levels — between about 30 and 60 dB — than at either higher or lower levels. Near the masked as well as the absolute threshold, the loudness decreased as  $\Delta F$  was increased beyond the critical bandwidth. Only when  $\Delta F$  was less than a critical band, was loudness independent of  $\Delta F$  and was the amount of loudness summation invariant with level. These results support the hypothesis that the amount of loudness summation depends upon the slope of the loudness functions for the individual critical bands that form the complex.

#### 7961 SOME FACTORS AFFECTING THE ESTIMATION OF LOUDNESS. R.P. Hellman and J. Zwischlocki.

J. Acoust. Soc. Amer., Vol. 33, No. 5, 687-94 (May, 1961).

In order to obtain a reasonably unbiased loudness function near the threshold of audibility by the method of magnitude estimation, several possible causes of bias were investigated. The investigation included a comparison between sound pressure level and sensation level as independent variables and a parametric variation of the reference SL and of the reference number. It is established that for certain pairs of reference SL's and reference numbers a reasonably unbiased loudness function can be determined down to a SL of 4 dB.

#### 7962 LOUDNESS AND LOUDNESS LEVEL. G.G. Sacerdote.

J. Acoust. Soc. Amer., Vol. 30, No. 12, 1165-6 (Dec., 1958).

The Technical Committee 43 of the International Organization for Standardization has proposed a relation between loudness  $S$  (sones) and loudness level  $P$  (phons):  $\log_{10} S = 0.03 (P - 40)$ .

#### 7963 SUBDIVISION OF THE AUDIBLE FREQUENCY RANGE INTO CRITICAL BANDS (FREQUENZGRUPPEN).

E. Zwicker.

J. Acoust. Soc. Amer., Vol. 33, No. 2, 248 (Feb., 1961).

A recommended subdivision is proposed. A table gives the proposed centre frequencies and bandwidths and a graph shows the relation between the subjective division into critical bands and frequency. The "bark" is defined; 1 bark corresponds to the width of one critical band and approximates to 100 mels.

H.D. Parbrook

#### 7964 NOTES ON A TECHNIQUE FOR THE DETERMINATION OF HIGH-FREQUENCY HEARING THRESHOLDS.

H.J. Page and J. Rutschmann.

J. Acoust. Soc. Amer., Vol. 30, No. 12, 1164-5 (Dec., 1958).

In an attempt to develop a method for measuring auditory acuity for high-frequency tones, the authors discuss pilot experiments in progress using an electromagnetic method for setting the eardrum into vibration (alternating magnetic fields acting on a permanent magnet fixed to the eardrum).

#### 7965 NONINTERACTION OF TEMPORARY THRESHOLD SHIFTS. W.D. Ward.

J. Acoust. Soc. Amer., Vol. 33, No. 4, 512-13 (April, 1961).

A 1 hr exposure to a high-frequency noise (2400-4800 c/s at 100-dB SPL) was (a) preceded or (b) followed by a 1 hr exposure to a low-frequency noise (600-1200 c/s at 110-dB SPL). Although both noises produced considerable temporary threshold shifts at frequencies just above the corresponding noise frequency, neither had any effect on the growth or recovery of shifts produced by the other. It is concluded that the course of the fatigue process at one area of the basilar membrane is relatively independent of conditions existing at other areas.

# LIST OF JOURNALS

The following list supplements the List of Journals published with the January number of Vol. 64 (1961). Reprints of the List of Journals can be obtained from The Institution of Electrical Engineers, Savoy Place, London, W.C.2, price 2s.0d. post free. The addresses given are believed to be correct at the date of publication, but no responsibility can be accepted for errors.

|   |   |
|---|---|
| Appl. Phys. Quart. (India)                                    | Applied Physics Quarterly (Formerly: Journal of Association of Applied Physicists)<br>Subscription address: The Technical Journals of India Private Ltd.,<br>24, Brabourne Road, Calcutta-1.      |
| J. Sci. engng Res. (India)                                    | Journal of Science and Engineering Research<br>Kharagpur, India.  |
| Photogr. J. (GB)  | Photographic Journal<br>The Royal Photographic Society, 16 Princes Gate, London, S.W.7.   |
| Reactor Sci. Technol. (GB)                                    | Reactor Science and Technology (Journal of Nuclear Energy. Parts A and B)<br>[Formerly: Reactor Science]<br>Pergamon Press, Headington Hill Hall, Oxford; 122 East 55th Street, New York 22, N.Y. |
| Trans Roy. Instn Naval Archit. (GB)                           | Transactions of the Royal Institution of Naval Architects (Formerly: Transactions of the Institution of Naval Architects)<br>10 Upper Belgrave Street, London, S.W. 1.                            |
| Wiss. Z. Humboldt-Univ. Berlin,<br>math.-nat. Reihe (Germany) | Wissenschaftliche Zeitschrift der Humboldt-Universität zu Berlin, Mathematisch-naturwissenschaftliche Reihe<br>Unter den Linden 6, Berlin, W.8.   |

## NEW JOURNAL

|                     |   |
|---------------------|---|
| Infrared Phys. (GB) | Infrared Physics<br>Pergamon Press, Headington Hill Hall, Oxford; 122 East 55th Street, New York 22, N.Y.<br>Quarterly. Vol. 1, No. 1, dated March, 1961. |
|---------------------|---|

## CHANGE OF TITLE

|                                    |  |
|------------------------------------|--|
| J. Assoc. Appl. Physicists (India) | Journal of Association of Applied Physicists<br>Title changed to: Applied Physics Quarterly (Appl. Phys. Quart.) with Vol. 6, 1959-60.   |
| Reactor Sci. (GB)                  | Reactor Science<br>Title changed to: Reactor Science and Technology [Reactor Sci. Technol.]<br>with issue dated No. 1, April, 1961.  |
| Trans Instn Naval Archit. (GB)     | Transactions of the Institution of Naval Architects<br>Title changed to: Transactions of the Royal Institution of Naval Architects<br>[Trans Roy. Instn Naval Archit. ] with Vol. 102, 1960. |

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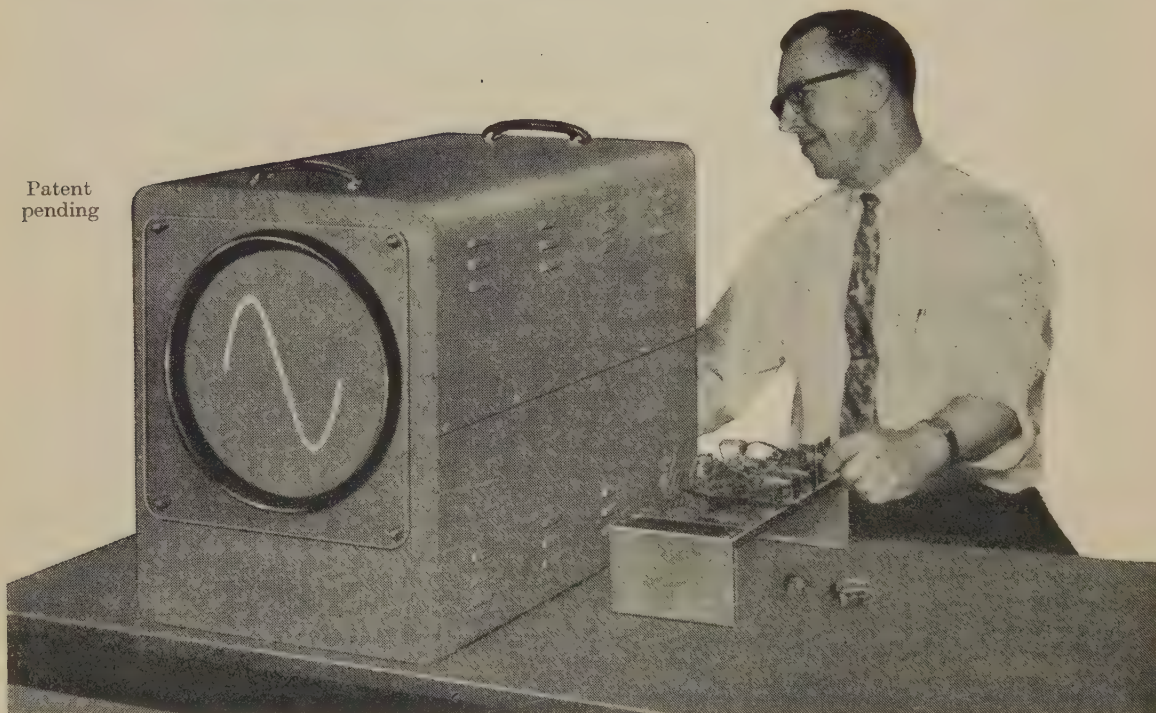
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